Aircraft
YDRAULIC EQUIPMEN

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NAVY TRAINING COURSES

AIRCRAFT
HYDRAULIC EQUIPMENT

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PREFACE

This book is written for the enlisted men of Naval Aviation. It is one of a series of books designed to give them the necessary information to perform their aviation duties.

A knowledge of aircraft hydraulic equipment is of primary importance to Aviation Hydraulics Mechanics. But Aviation Machinist Mates responsible for general maintenance work and other subdivisions of Aviation Machinist Mates—that is, Aviation Instrument Mechanics, Aviation Carburetor Mechanics, Aviation Propeller Mechanics and Aviation Flight Engineers—all of them can profit by an understanding of aircraft hydraulic equipment. So can Aviation Turret Mechanics. Specialists should not be narrowly limited to their specialties alone. They should know how their jobs relate to other jobs.

Starting with the basic principles of hydraulically operated mechanisms, this book proceeds with a discussion of primary units, secondary units and special valves. Then attention turns to the operation of hydraulic brakes, struts and turrets. The hydraulic system of four outstanding Navy airplanes—the Corsair, the Dauntless, the Avenger and the Hellcat—are taken up in detail. In conclusion, there is a section on the maintenance of hydraulic equipment with special emphasis on trouble shooting.

As one of the NAVY TRAINING COURSES, this book represents the joint endeavor of the Naval Air Technical Training Command and the Training Courses Section of the Bureau of Naval Personnel.

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AIRCRAFT HYDRAULIC EQUIPMENT

CHAPTER 1

HOW IT WORKS

WHY HYDRAULICS?

When a bombardier reports "BOMB BAY DOORS OPEN," what is it that opens the doors?

In many types of Naval aircraft, they are opened by means of applied hydraulics. Also the landing gear is retracted and extended, wing flaps are raised and lowered, brakes are operated, machine-gun turrets are rotated, cowl flaps are opened and closed, target cable reels are rewound, and a whole slew of odd jobs done by hydraulically actuated mechanisms.

In fact, as you can see in figure 1, hydraulically operated mechanisms can do just about everything but run the engine and feed the crew.

Why not use electricity or compressed air to operate these devices? Both are as reliable. BUT hydraulic equipment has many advantages. First of all, the necessary electric apparatus is much heavier than the hydraulic apparatus. And weight is of paramount importance in aircraft. Other outstanding advantages of the hydraulic equipment are simpler maintenance, economy, adaptability to

heavy load conditions, and instant response for starting or stopping. Compactness, too, is important in aircraft equipment. Hydraulic systems take up comparatively little room because the working parts are not bulky and can be distributed about the airplane in protected and out-of-the-way places.

Of course, the hydraulic system isn't foolproof. But there isn't too much danger of it getting out of kilter. And if it should, it is equipped with several emergency controls. The only serious danger of failure is the possibility of broken feed lines or pressure tubes and that's guarded against by running the lines where they are protected from ordinary hazards.

THE A B C's OF HYDRAULICS

You have been familiar with some of the practical aspects of hydraulics ever since you first experimented with a water pistol. As a matter of fact, you have come in contact with the so-called principles of hydraulics all your life. As a mechanic, however, it is important that you have a clear understanding of these principles.

So take some time right now to get straight about the properties of liquids in a closed container. They constitute the ABC's of hydraulics.

From the mechanic's standpoint, LIQUIDS ARE NON-COMPRESSIBLE. That means you can't squeeze them into a smaller space.

Furthermore, LIQUIDS IN A CLOSED CONTAINER WILL ALWAYS REGISTER A PRESSURE RISE WITH AN INCREASE IN TEMPERATURE.

And finally, ANY PRESSURE APPLIED TO A CONFINED LIQUID IS TRANSMITTED UNDIMINISHED TO ALL PARTS OF THE CONTAINER AND EXERTS ITS FORCE AT RIGHT ANGLES TO THE WALLS OF THE CONTAINER. A French philosopher named Pascal discovered this principle of hydraulics some 300 years before the first hydraulically-equipped bomb-

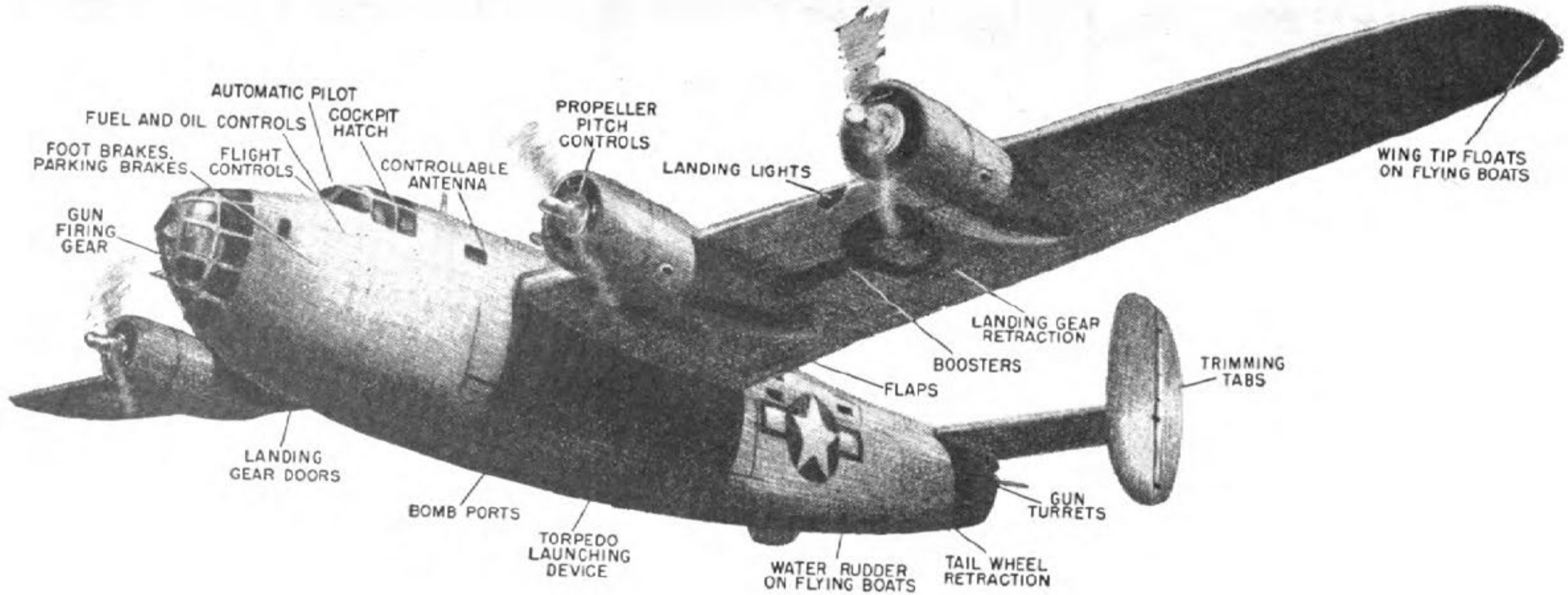


Figure 1.—Uses of hydraulics in aircraft.

ers dropped their eggs on the continent of Europe. This principle is known as PASCAL'S LAW.

Now, to understand these ABC's, have a look at figure 2. Examine the manner in which pressure is transmitted through a liquid.

If you apply a force of 50 pounds on a small piston of 2 sq. in. area, it will create a 25-pounds-per-square-inch pressure in the liquid. Why? Well, it's just simple arithmetic.

$$50 \text{ lbs.} \div 2 \text{ sq. in.} = 25 \text{ psi}$$

The 50-pound force is equally distributed over the

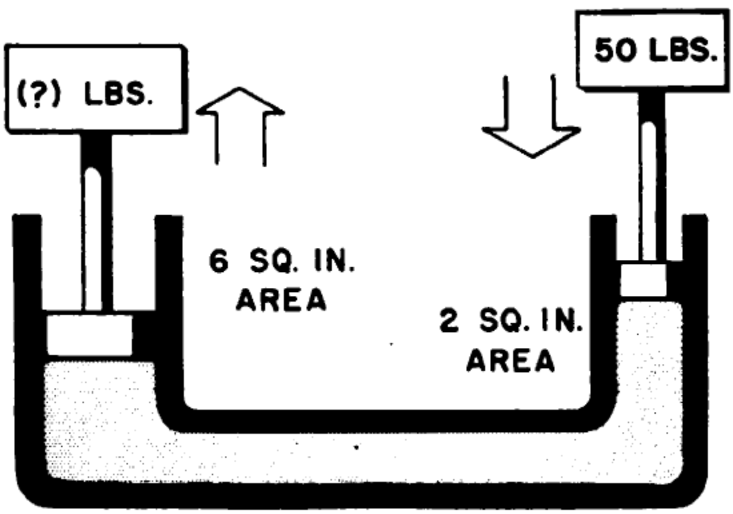


Figure 2.—Simple hydraulic device.

2 square inches area, causing a 25-pound force to be exerted on each square inch of the liquid.

Actually, pressure is the result of the force applied to each square inch area of the liquid. Using a formula, you can say that PRESSURE is the FORCE divided by the AREA.

$$P = \frac{F}{A}$$

Now the question is, WHAT will be the pressure acting on each square inch of the large piston? Obviously, if the pressure is transmitted undiminished, 25 pounds per square inch will act on each square inch of the large piston.

You might ask, how much of a load could you support on the large piston? Well, if you have 25 pounds per square inch acting on each square inch, and if you have 6 square inches area on the large piston, then the total upward force on the large piston will be 150 pounds.

$$25 \text{ psi} \times 6 \text{ sq. in.} = 150 \text{ lbs.}$$

Thus you can see that a small force on a small piston creates a pressure which, acting on the large piston, produces a large force.

And, if you want a simple analogy of this in an airplane hydraulic system, just consider the hand pump and the landing gear cylinder. By creating a pressure with the small hand pump piston, a pilot can raise the heavy landing gear. Why? Because, although the pressure remains the same, the landing gear piston has more square inches for pressure to act upon. So you have a larger force there.

PISTON TRAVEL

Here's another question that may occur to you.

If you can multiply a small force and get a larger force, WHAT do you lose? Obviously, with a gain in force you must suffer the loss in distance traveled by the large piston. Although the pilot can raise the heavy landing gear with his small hand pump, he must move the piston through a greater distance than the large landing gear piston moves.

Look back at figure 2 again. Assume that the small piston there travels down a distance of 12 inches. To determine how far up the large piston will move, you must first calculate how much fluid will be pushed out, or DISPLACED, from the small cylinder. You can do this easily, by multiplying the area of the small piston by the distance through which it moves.

$$2 \text{ sq. in.} \times 12 \text{ in.} = 24 \text{ cu. in.}$$

The answer is 24 cubic inches of liquid. Because LIQUIDS ARE NON-COMPRESSIBLE, the large piston will have to move up far enough to accommodate the additional 24 cubic inches of liquid from the small cylinder.

You merely divide the area of the large piston into the volume displaced by the small piston to find out the distance the large piston travels.

$$24 \text{ cu in.} \div 6 \text{ sq. in.} = 4 \text{ in.}$$

The answer is 4 inches. And from this you can see that, although the large piston will develop greater force, it will exert that greater force through a shorter distance.

HYDRAULIC JACK

Now take a look at figure 3. There you have a simple hydraulic mechanism. It is known as the hydraulic jack.

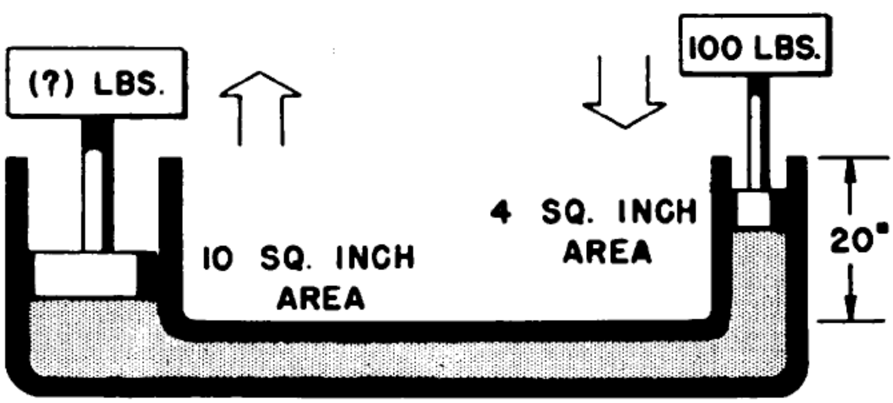


Figure 3.—Hydraulic jack.

If you push down on the handle, the oil is forced under pressure into the large cylinder. How come? Well, because the ball check valve is designed so that it permits the oil to flow only in one direction. The check valve to the cylinder is forced open, and the one between the pump and the reservoir closes. Then on the return, or UP STROKE, there is a decreased pressure area in the pumping cylinder,

allowing the pressure in the large cylinder to seat that check valve.

However, because of the decreased pressure area in the pumping cylinder (pressure below atmospheric pressure), the check valve in the line from the reservoir opens.

It is important here to understand WHAT opens that check valve.

The decreased pressure area or suction does NOT pull it open. A decreased pressure area is NOT the existence of a pulling force. IT IS THE LACK OF A PUSHING FORCE. Therefore, the ball check is NOT pulled open by decreased pressure, but rather it is PUSHED open by the greater oil pressure in the reservoir. The oil pressure in the reservoir is due to the weight of the liquid plus the atmospheric pressure acting on its surface through the vent lines.

When the pumping piston is in full UP position, the procedure is repeated again as many times as is necessary to raise the large piston to its desired height. To lower the large piston, all you do is open the shut-off valve in the return line. This allows the oil a free flow back to the reservoir, and the return spring pushes the piston down.

SIMPLE HYDRAULIC SYSTEM

Essentially, an hydraulic system consists of four units.

First, you have a RESERVOIR to supply hydraulic fluid. Next, a PUMP to create a flow of fluid under pressure. Next a SELECTOR VALVE to direct the flow of fluid. And finally, you have an ACTUATING CYLINDER to convert the fluid under pressure to mechanical motion.

Look at figure 4, which is a diagram of a simple hydraulic system. Note the reservoir, the pump, the selector valve, the actuating cylinder. It has all the essential units.

The selector valve is the rotary plug type, represented schematically here, and consists of a HOUSING, a NOTCHED PLUG (which rotates inside the housing), and a HANDLE (which turns the rotary plug).

Note the four ports in the selector valve, pressure and return ports, one for each cylinder line. In the position shown in the diagram, the plug is connecting the pump pressure port and up cylinder line which retracts the flaps. The piston could not move if the fluid in the other side of the cylinder were trapped.

However, the fluid can pass back through the selector valve down port, into the return port, and back to the reservoir. Then, to put the flap down, the selector valve handle is merely placed in the flaps-down position. This action reverses the flow of fluid to and from the flap actuating cylinder, forcing the flaps down.

Remember this. It is important that you get the lines hooked up properly. The actuating cylinder ports on a rotary plug selector valve are always perpendicular to the pressure and return ports.

HYDRAULIC LINES

Hydraulic lines are the stretches of TUBING which connect up the various units of a hydraulic system. In aircraft, these lines are marked with blue-yellow-blue bands spaced at frequent intervals, for rapid identification.

Four types of tubing are commonly in use. ALUMINUM ALLOY tubing is found on systems with 1,500-psi system pressure or less. EVERDUR tubing, however, because of its greater strength, is in some instances replacing aluminum. Everdur is a copper base alloy. STAINLESS STEEL tubing is used primarily on systems with a working pressure in excess of 1,500 psi, or where a line is liable to encounter heat or abrasion. SYNTHETIC AND NAT-

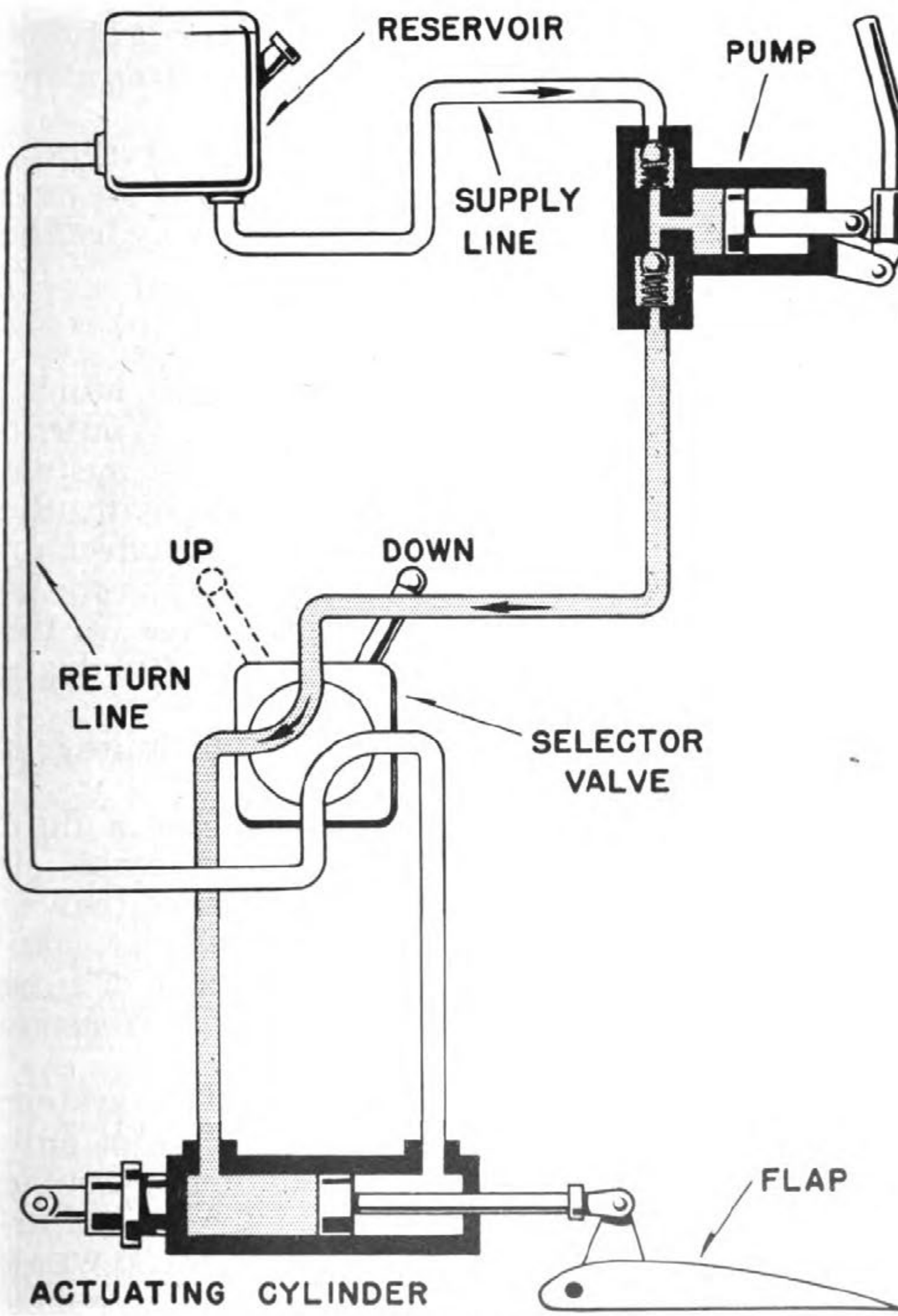


Figure 4.—Simple hydraulic system.

URAL RUBBER tubing, along with fabric, is used where flexible hose construction is necessary. Designed for moving parts and to absorb vibrations, flexible hose has the disadvantage of deteriorating rapidly under operating conditions.

You have TUBE CONNECTORS and TUBE FITTINGS—many different shapes and sizes—all for the purpose of helping you tap the lines of a hydraulic system where you NEED to tap them.

HYDRAULIC FLUIDS

An aircraft hydraulic system, like the human body, is dependent upon a fluid for life. You can "bleed" a little of the fluid out of the system once in a while, but a major break in a hydraulic feed line will have just about the same effect on the hydraulic system as a severed artery has on the human body. Either system simply gives up the ghost when its life-giving fluid is allowed to drain out of the supply lines.

There are different types of hydraulic fluids just as there are different types of blood.

Airplane hydraulic systems use either a fluid with a mineral oil base or one with a vegetable oil base. They are not interchangeable. Neither is blood. Type A blood transfused to one of your mates with type B blood is merely a waste of time—and precious blood. That's one of the reasons you wear a dog tag.

Putting a mineral oil in a hydraulic system designed for a vegetable oil base fluid is not only a waste of time—it's a sure way to create trouble and RUIN YOUR REPUTATION as an aviation technician. THAT'S WHY HYDRAULIC SYSTEMS ALSO WEAR DOG TAGS!

The hydraulic system's dog tag is a plate attached in a prominent spot on the system. It tells you the kind of fluid for which the system was designed—the only kind you should put in it.

The human system and the hydraulic system are alike in still another way—BOTH HAVE RED AND BLUE BLOOD.

If your forefathers came over on the Mayflower, you're supposed to have blue blood. If they missed the boat and had to wait a few years to cross the Atlantic, then your blood is red.

In the hydraulic system, a fluid with a vegetable-oil base is colored BLUE and one with a mineral-oil base is colored RED.

The difference in the color of blood is purely imaginary but the difference in the color of hydraulic fluid is the real McCoy. Put a red fluid in a blue system and you endanger the lives of every member of the plane's crew. THAT'S IMPORTANT. REMEMBER IT!

Fluids with a mineral-oil base are used in most Naval aircraft hydraulic systems but you will have to work with both types of oils. There is no general rule for deciding which make or type of airplane uses which type of oil.

Just because you have used vegetable base oil in the brake system of an F4F, don't take it for granted that it's to be used in an F6F. Likewise, if you've used a mineral base oil in the brake system of a JRS1, don't decide that you should use the same red fluid in the landing-gear hydraulic system.

Guesswork is out when you're working around an airplane. That dog tag on the hydraulic system is put there for a purpose. USE IT.

You wouldn't think much of a pharmacist's mate who took a quick look at you on the transfusion table and said "Give him some Type O, he looks like a Type O guy." You surely wouldn't if the dog tag around your neck said "Type A."

Get the wrong oil into a system and the packings and seals will deteriorate as rapidly as your bankroll on liberty.

Generally speaking, natural rubber packing and rubber hose are used in systems employing a vegetable-base fluid. Synthetic materials are used in systems where mineral-base oil is required. Mineral oils ruin natural rubber packing—vegetable oils have the same effect on synthetic packings.

Use this rule—

VEGETABLE OIL FOR VEGETABLE (natural rubber) PACKINGS.

MINERAL OIL FOR MINERAL (synthetic) PACKINGS.

You'll find packings with a **V**-shaped cross section on most of the older airplanes you work on.

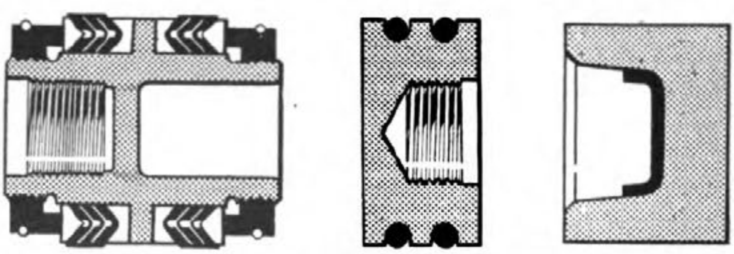


Figure 5.—Chevron, "doughnut" and cup packings.

They are known as CHEVRON TYPE oil seals. The hydraulic systems on newer aircraft employ packings with circular or **U**-shaped cross sections. All three types are illustrated for you in figure 5. Always replace a packing with one of the same type.

Chevron packings work better in one direction than in the other. An increase in fluid pressure acting against the flexible lip of the packing in the proper direction causes the sealing properties to be improved. Consequently, chevron packings are always installed so that half of them face one way and the others face the opposite end of the piston. This assures a seal whichever way the piston moves. If all chevron packings faced the same way, the seal would be excellent when the piston

moved in one direction but pretty awful when it moved the other way.

And here's another point to remember!

EXCESSIVE TIGHTENING of the packing retainer nut on chevron packings REDUCES rather than increases its sealing properties. Too tight a retainer nut also INCREASES packing friction and interferes with proper operation of the unit.

Because of their shape, circular packings are frequently called "doughnut" packings and U-type packings are called "cup" packings.

Of course, you may wonder, why do you need packings at all? What purpose do they serve in a hydraulic system?

They serve to seal pressure in the system, and sometimes to keep air out. Where units join the lines, you have DANGER SPOTS. And you will discover, as you proceed in the study of hydraulics, that there are many more units than the essential four you have met so far. You have primary units, secondary units, and all kinds of special valves. Wherever you have units, you will have moving parts, access ports, etc. And they all require packings or seals.

CHAPTER 2

PRIMARY UNITS

RESERVOIRS

As its name suggests, the reservoir is the storage tank for the hydraulic fluid supply. It is the starting point for the fluid, so suppose you begin at the beginning and learn what it is, what it does, and how it operates.

The reservoir serves as a tank from which the fluid is supplied to the pumps and to which excess fluid forced out of the system is returned.

When additional fluid is needed in the system, either for operating additional units or to replenish fluid lost through leaks or seepage, the pump can draw that fluid from the reservoir. Furthermore, when increased temperatures cause the fluid to expand, the excess is delivered to the reservoir. The reservoir also provides a place where the fluid can settle and get rid of any air bubbles that have formed in the system. Foreign matter in the fluid is removed in the reservoir by filters, sumps, or similar devices.

Figure 6 shows you what a typical reservoir looks like. Notice that the VENT LINE rises from the top of the tank, runs down along the right side, and turns under the tank. This air line serves three purposes.

FIRST, it exposes the fluid in the reservoir to

atmospheric pressure. Thus, a vacuum cannot form inside the reservoir; nor can air pressure build up.

SECOND, it serves as a spill pipe for excess fluid that accumulates in the reservoir.

And, THIRD, it allows the escape of any air that is carried into the reservoir from small trapped-air pockets in the lines and operating units.

KEEP THIS VENT CLEAN AT ALL TIMES.

Now look at the FILLER PIPE on the left-hand side of the drawing. Notice that it enters at a point considerably BELOW the top of the reservoir. This is to prevent over-filling and to provide a space above the fluid for expansion when the reservoir is filled to its normal level. Expansion results from increases in temperatures and from foaming of the liquid.

The filler cap is leaktight so that the fluid can't leak out when the airplane is maneuvering or when the fluid expands. The measuring rod attached to the filler cap indicates the level of the fluid in the reservoir, in much the same manner as the oil measuring stick in the crankcase of your automobile. Some reservoirs use a glass sight-gage instead of the measuring rod.

The BAFFLES and FINS inside the tank prevent excessive foaming or turbulence of the fluid when the fluid is flowing back from the return lines.

Now shift your glance to the STANDPIPE connected with the power-pump suction line at the bottom of the tank. Note that its inlet IS CONSIDERABLY ABOVE THE BOTTOM OF THE TANK—and for a good reason too!

This arrangement prevents the power pump from ever using up all the fluid in the tank. Thus, when the power pump ceases to function, there's still enough fluid available for the hand pump.

Instead of using a standpipe, some systems

get the same results by attaching the power pump outlet to the side of the reservoir at a point above the bottom of the tank.

The FLUID RETURN LINE usually enters the reservoir at a spot below the normal level of the fluid in the reservoir in such a manner as to cause the least possible disturbance of the fluid. In figure

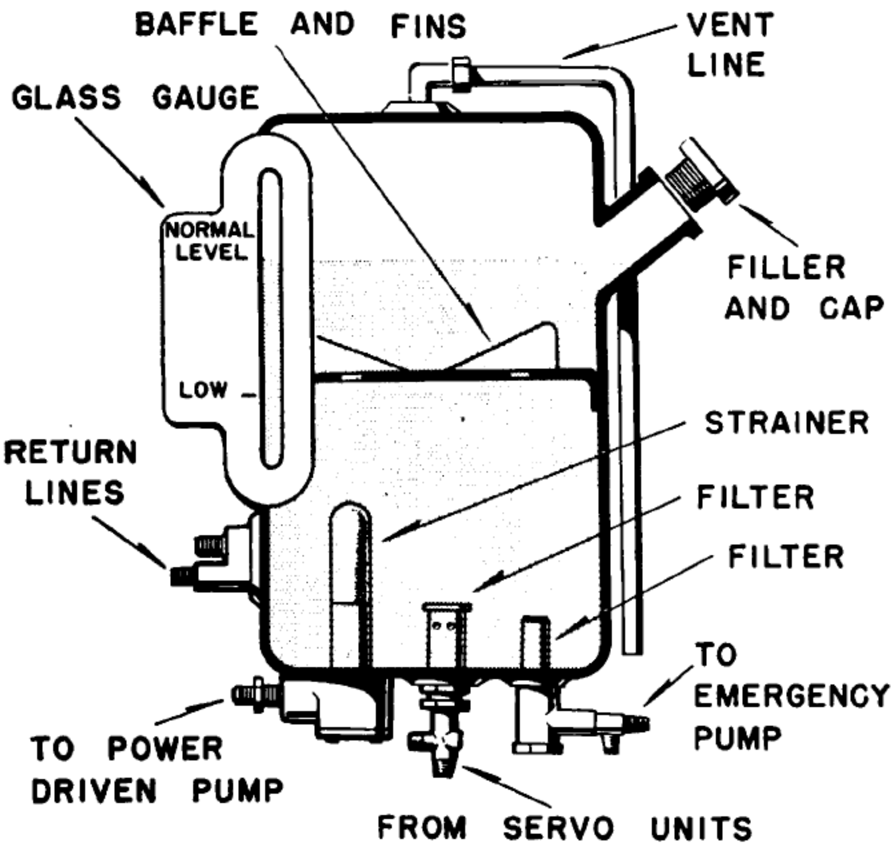


Figure 6.—Reservoir.

6, this is accomplished by attaching the return line at a tangent to the reservoir shell.

HAND PUMP

Hydraulic fluid is drawn out of the reservoir by a pump. The main pump is power driven and is either a gear pump or a piston pump. A hand-operated auxiliary pump is also provided.

This hand pump is installed in aircraft hydraulic systems to serve as a substitute for the

power pump in case of emergency, and as a source of power for checking the system when the engines are not running. Figure 7 shows a double-acting, single-piston pump.

The term "double-acting" is used because the pump discharges fluid during both strokes of the handle—up and down.

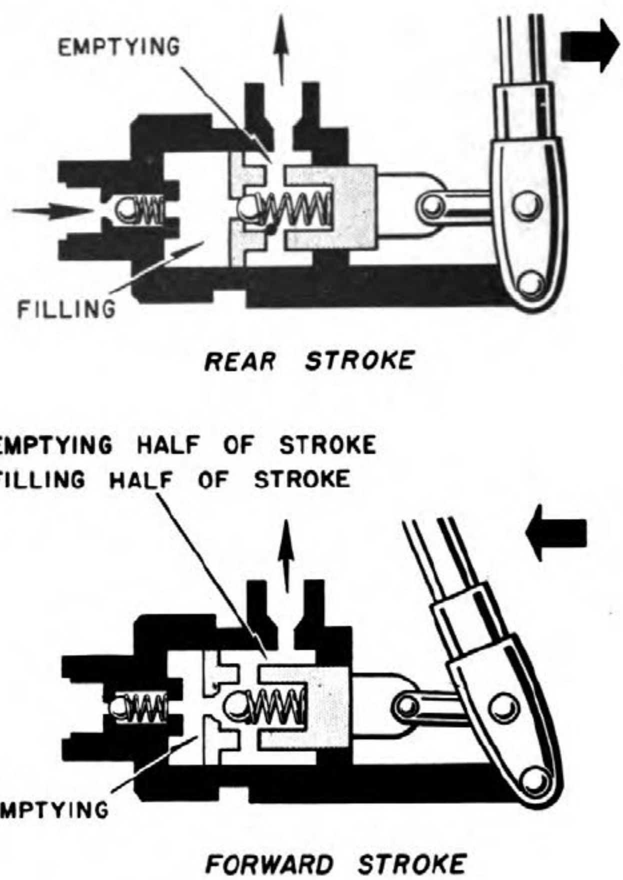


Figure 7.—A hand pump.

One look at figure 7 and you can tell that the hand pump is really very simple in construction. It consists essentially of a cylinder having inlet and outlet ports, a piston, and a handle for operating the piston. Throw in a few necessary check valves, packings and seals and that's the works.

Here is how the pump operates.

You pull the handle toward the right, thereby

moving the piston toward the left. The liquid in front of (to the left of in the illustration) the piston is forced out of the cylinder through the check valve of the outlet port. Meanwhile the piston is drawing in fluid through the inlet valve to the right. Then, when you pull the pump handle back toward the left, the piston moves to the right. Thus liquid is forced out of the right-hand end of the cylinder while more liquid is flowing into the left-hand end.

The check valves in the inlet ports prevent the fluid in the pump from being forced back into the reservoir. The check valves in the outlet ports prevent the fluid in the system from being drawn back into the pump.

PISTON POWER PUMP

There are several basic models of piston-type hydraulic pumps. The ones you'll run into most

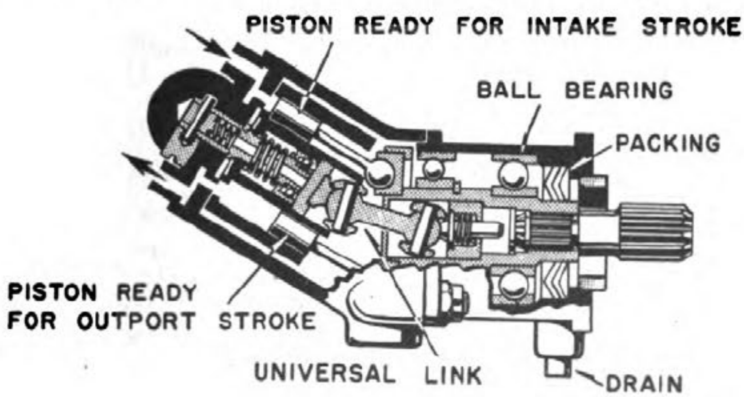


Figure 8.—Vickers piston pump.

often in the Navy are the axial and radial types. Of these, the one used most generally is the "Vickers" pump, which is the axial type. It is shown in figure 8 in cut-away form.

Things are getting a little more complicated so you better take a good long look at this cross-sectional drawing. Note that the cylinder block is positioned at an angle to the driving mechanism.

There are 7 cylinders spaced equally around the cylinder-block axis and the cylinder bores are parallel to that axis. The cylinder block is linked to the driving mechanism by a universal block so that the driving mechanism and cylinder block rotate at the same speed.

When the driving mechanism and cylinder block are rotated, the position of each piston in its cylinder is changed. This is due to the change in the distance from the cylinder to the point where the piston rod is linked to the drive mechanism.

As this driving mechanism and the cylinder block are thus rotated about their axes and the pistons start their movement away from the cylinder head, a port in the cylinder head opens to allow fluid to be drawn into the cylinder.

When the piston reaches the bottom of its stroke, the discharge port is opened and fluid is forced from this port to the system by the upward motion of the piston. This cycle is repeated as each piston travels down, and then up, in its cylinder.

You'll find in the course of your work that other multiple-piston pumps operate on the same principle although they differ in details of construction. The multiple-piston pump is the most powerful used in aircraft hydraulic systems. Some models can develop a working pressure up to 3,000 pounds per square inch.

GEAR PUMP

The gear-type pump consists essentially of a pair of closely meshed steel gears in a housing with a close-fitting cover. Gear pumps are designed for continuous operation at pressures up to 1,000 pounds per square inch and may be used intermittently at pressures up to 1,500 pounds. They are made in various capacities to meet the requirements of different installations.

Figure 9 gives you a simple picture of how the hydraulic fluid goes through a typical gear pump.

The pump operates in the following manner.

Torque is transmitted from the engine accessory drive, through a coupling, to the pump drive gear. The pump drive gear and the driven gear with which it is in close mesh are contained in a housing with sufficient clearance only for the gears to turn freely.

Rotation of the pump drive gear in either direction causes the driven gear to rotate in the opposite direction.

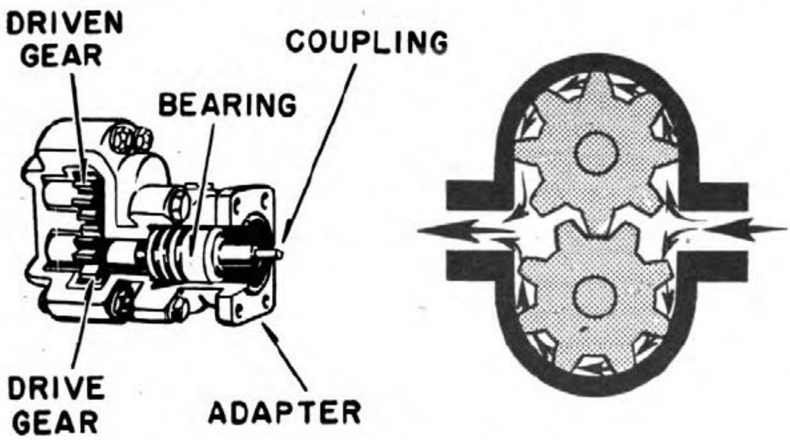


Figure 9.—A gear pump.

This rotation of the gears within the close-fitting housing causes fluid to be drawn into the spaces between the gear teeth, and to be carried by the teeth to the opposite side of the pump.

When the fluid reaches the point where the gear teeth engage, it is forced out through the pump-discharge port and into the hydraulic line.

Gear-type pumps can be installed usually so as to operate with either clockwise or counterclockwise rotation of the drive gear. In some cases, however, it is necessary to change the position of the pump cover to change the direction of rotation. Arrows pointing to the intake and discharge ports for either direction of rotation are usually

stamped on the pump body or on a metal plate attached to it.

The principal parts of a gear pump are the body, cover, drive coupling, drive shaft, oil seal and a pair of spur gears.

The PUMP BODY is an aluminum-alloy casing with a bronze insert. The body houses the drive mechanism, the seals, and the two gears. The bronze insert may be cast integral with the pump body or may consist of removable bronze bushings. The pump body is provided with an integral mounting flange or an adapter secured to the pump by capscrews.

The PUMP COVER contains the pump inlet and outlet ports. It is bolted to the pump body and contains seal-type bronze bushings which serve as bearing surfaces for the gears and as guides for the gear-shaft journals.

Some pumps are fitted with covers containing integral ball-check valves. The pump cover is provided with drilled passages between the intake port and the ends of the gear-shaft bushings. This is to prevent fluid pressure from building up between the gear shafts and their bushings.

The DRIVE COUPLING transmits the rotation of the engine accessory drive to the pump gear drive. This coupling usually rotates on a ball bearing mounted in the pump body or in the adapter. The coupling may engage directly with the drive gear or may transmit its motion through a universal block. In either case, the coupling is fitted with a SHEAR SECTION for protecting the pump and engine accessory drive from excessive loads. Under such condition, a shear pin gives way and the coupling turns free of the mechanism beyond it. Of course, this calls for correction of the condition that caused the shearing and replacement of the shear pin.

The PUMP SEAL is designed to minimize leakage

of the working fluid into the pump adapter or engine end of the pump body. There are two general types of seals used in gear-type pumps—the spring-type seal and the pressure-type seal.

In the SPRING-type seal, a metallic seal is held in position in the pump body by a helical spring. This spring provides sufficient thrust to make the seal effective.

In the PRESSURE-type seal, a metal disk and a rubber seal ring are used. Tension on the seal is maintained by the pressure of the fluid leaking past the drive shaft and acting on the coupling. This pressure holds the coupling against the seal disk and, in turn, holds the disk against the seal ring. The seal ring, being between the seal disk and the pump adapter, reduces fluid leakage to a minimum.

A light coil spring in this type of seal provides a seal before pressure is developed by the pump, or when pressure is low. Drain holes, in the adapters of pumps using either type of seal, allow any fluid leaking past the seals to drain clear. This is to prevent hydraulic fluid from entering the engine accessory section.

PESCO GEAR PUMPS

Pesco gear pumps, of which several models are currently used, are medium-pressure pumps. Fluid from the intake port is carried in the teeth to the pressure port, where it is forced into the system by the mating action of the gears. One gear is driven by a drive shaft which is connected to the engine accessory section. The other is a driven, or idler, gear. The drive shaft has an undercut shear section to prevent damage to the accessory section of the engine in the event the pump should bind. Look at figure 10.

All Pesco gear pumps are designed with some means of relieving internal leakage. In some

"standard models" there are communication holes, drilled in the cover between the suction port and the top of the hollow gear shafts, to relieve internal leakage. For this reason the covers cannot be reversed without also reversing the pump's direction of rotation.

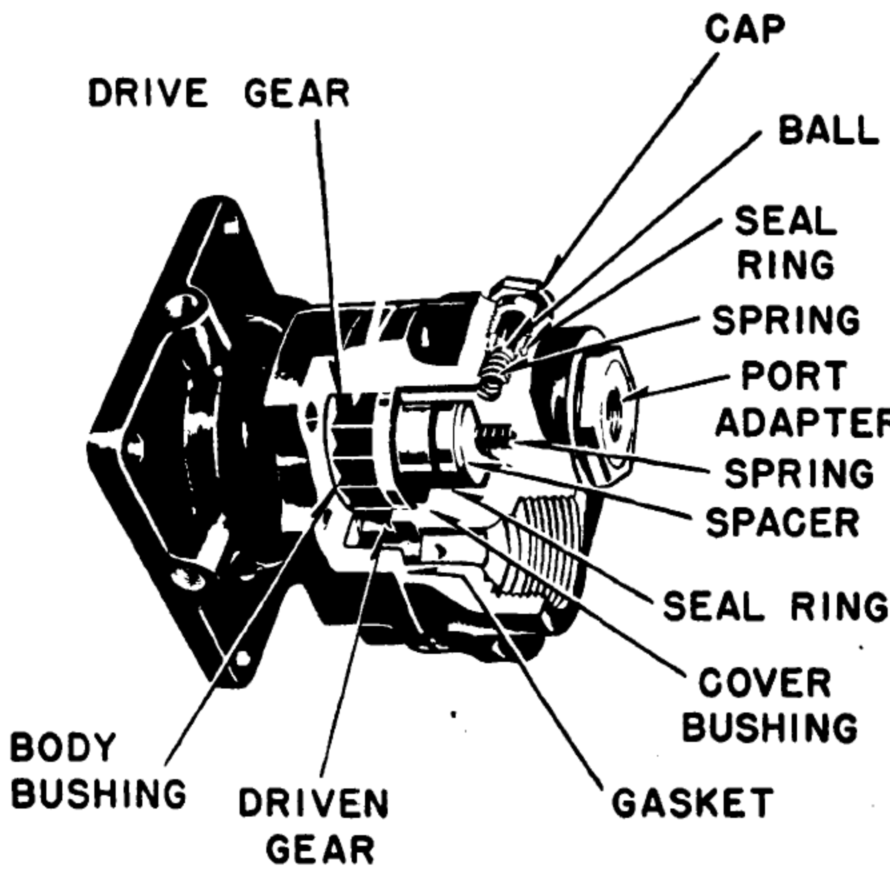


Figure 10.—Pesco gear pump.

If a pump cover should become reversed accidentally, the pressure acting through the communication hole from the pressure port might cause excessive friction between the gears and the bronze bushings, and result in leakage past the drive gear into the adapter section.

When installing a pump with a "standard" cover, make sure that the cover is mounted with the communication holes at the suction port. The direction of rotation is indicated by an arrow on

the mounting flange. If it is necessary to reverse the rotation of a pump, the cover must be reversed also.

The most recent models, however, are more easily reversible. With internal check valves in the cover of a "reversible" pump, the direction of rotation can be changed without reversing the cover. And, because of their construction, the covers can be installed in only one position.

If the pump shows excessive wear (and will not develop sufficient pressure), it should be repaired. You will find that excessive wear is generally limited to the cover bushings. Adjustment can be made by removing shims from between the housing and the cover until the drive shaft can just be turned by hand. To replace a sheared drive shaft, the adapter base must be removed from the pump housing.

SELECTOR VALVES

You now have the hydraulic fluid stored in a

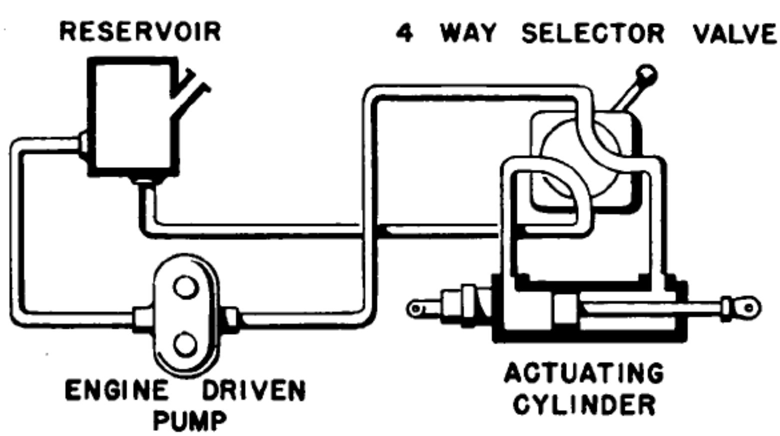


Figure 11.—Selector valve.

reservoir and then pumped through the system by pumps. But—the flow must be directed to the spot in the system where hydraulic pressure is to be used to perform a specific function at a specific time.

That job of directing is done by the SELECTOR VALVES.

Hydraulic selector valves are the control switches—the steering wheel—of the aircraft hydraulic system. They are used to direct the flow of fluid to, or from, the desired unit in the system. Thus, they control the fluid's direction of motion. There is usually a selector valve for each hydraulically operated unit in the system.

This valve is commonly called a FOUR-WAY selector valve because it has four ports for connection with the system. There are such things as two-way, three-way and five-way selector valves, but the four-way valves are most common in aircraft hydraulic systems. Figure 11 shows a typical installation using a selector valve to control the operation of an actuating cylinder in either direction.

Notice that a line from the pump enters the top of the selector-valve housing while a return line to the reservoir is connected to the bottom. There is also a line extending to each end of the actuating cylinder. By turning the valve, it is possible to direct the fluid from the pressure line to either end of the actuating cylinder. Fluid is forced from the opposite end of the actuating cylinder by the motion of the piston. This fluid is forced through an opening in the selector valve and returns to the reservoir where it is ready to be used again.

ROTOR, PISTON and POPPET-type selector valves are used in modern aircraft hydraulic systems. The rotor type is first on the list, so suppose you start with this one. Its construction is simplicity itself—an outer case that has four ports, an inner rotor, and a control handle.

The four ports are spaced at intervals of 90 degrees around the circumference of the valve case. The rotor contains two fluid passages, each

arranged so as to connect adjacent ports in the valve case.

WITHIN the rotor are two curved tubular channels, designed so that each channel will connect two adjacent ports. Which ports are connected by each channel depends upon the rotor's position. Thus in figure 12, one channel connects the pres-

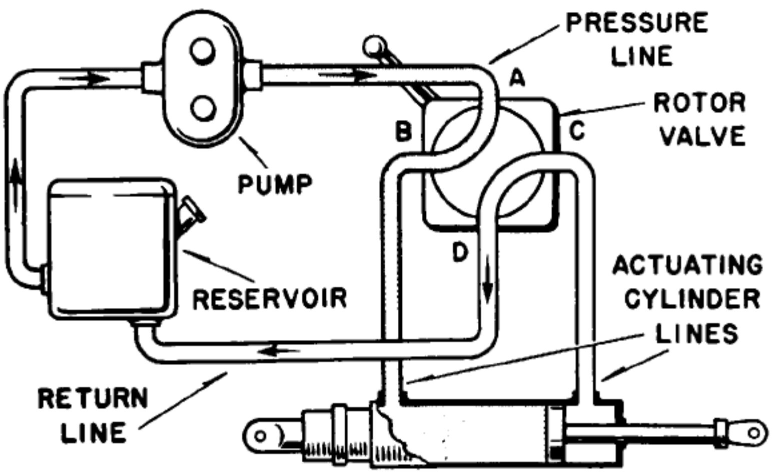


Figure 12.—The rotor selector valve in position 1.

sure inlet line (port *A*) with an actuating cylinder line (port *B*) and with the outlet line by ports *C* and *D*. With the rotor in this position hydraulic pressure enters the actuating cylinder in a direction which will move the piston to the RIGHT. The channel between ports *C* and *D* completes a passageway for fluid trapped behind the piston to return to the reservoir through the outlet line.

When the rotor is given a 90 degree turn, as in figure 13, the inlet line is piped to the actuating cylinder so that hydraulic pressure now enters the cylinder from the opposite direction, and moves the piston to the LEFT.

Thus, by operating the selector valve, you can control the direction of motion of the piston in the actuating cylinder.

the actuating piston in whatever position you

When you set the valve at NEUTRAL, you stop

desire and lock it in that position. This is particularly valuable in the case of wing flaps as it may be desired to lower the flaps only part way.

A PISTON-TYPE selector valve differs from the rotor type in its shape, location of ports, and the

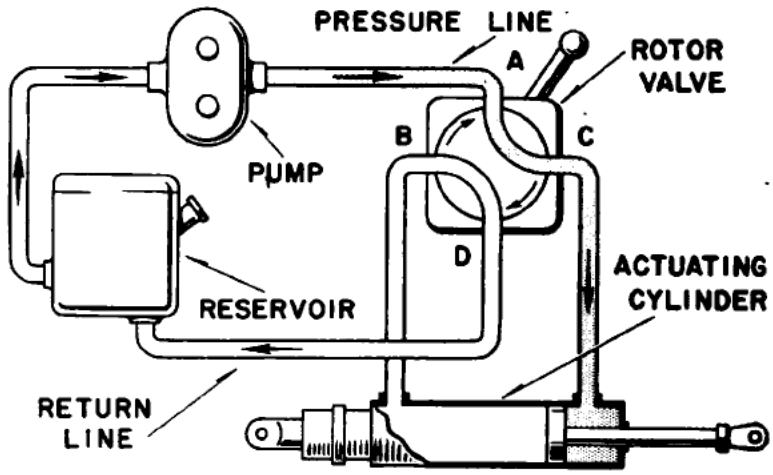


Figure 13.—The rotor selector valve in position 2.

method of controlling fluid flow through the valve. You see a cross-section drawing of the piston-type selector valve in figure 14.

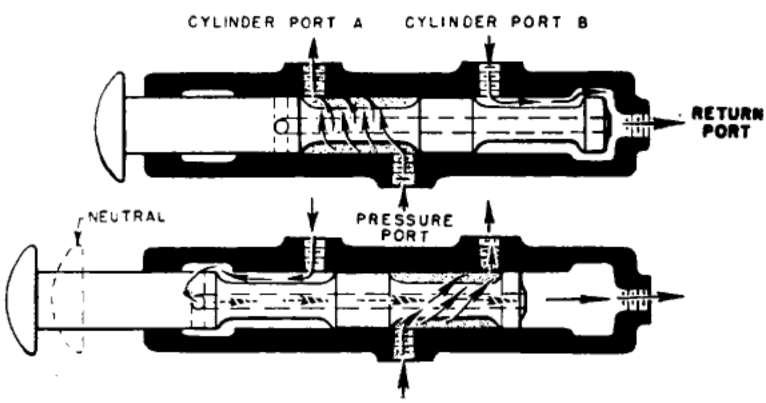


Figure 14.—How a piston selector valve works.

The direction of flow through the valve is determined by the position of a sliding hollow plunger within the valve case. With the plunger in the position indicated in the upper part of figure 14, the flow of fluid from the pressure port

to the actuating cylinder is through CYLINDER PORT (*A*).

Fluid from the opposite end of the actuating cylinder enters the valve through CYLINDER PORT (*B*) and is directed to the system return line by way of the valve return port. With the plunger in this position, the hole through the plunger is shut off from the fluid by the valve housing.

To direct the fluid flow from the pressure port through CYLINDER PORT (*B*) and thus to the opposite end of the actuating cylinder, the plunger is pulled out to the position shown in the lower part of the drawing. With the plunger

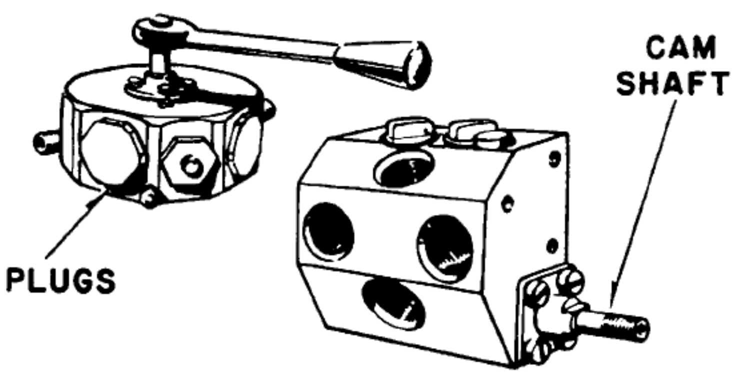


Figure 15.—Poppet selector valves.

in this position, the left-hand end is in an enlarged portion of the housing. Hence the return fluid enters the valve through CYLINDER PORT (*A*) and flows to the return port through the inside of the hollow plunger.

With the plunger in the neutral position, fluid flow in any direction is prevented. The operating principles of all valves of this type are essentially the same.

POPPET-TYPE selector valves are also similar in principle. In all of them, the fluid flow is controlled by 4 poppet valves similar to the exhaust and intake valves of a gasoline engine.

Figure 15 shows you what poppet selector

valves look like. Figure 16 shows you how one works. In the latter diagram, poppets 2 and 4 are open and poppets 1 and 3 are closed. The small circles represent springs which keep the valves against their seats unless otherwise actuated.

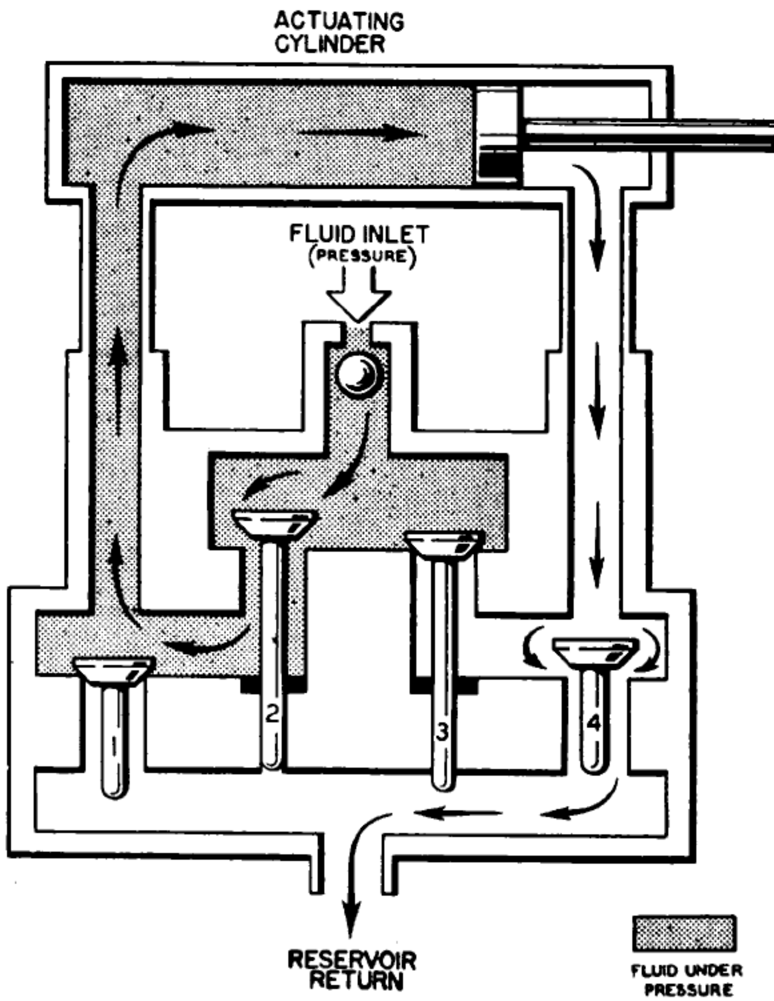


Figure 16.—How a poppet selector valve works.

With the poppets set like this, the flow of fluid from the system pressure line is directed as shown by the shaded portion of the diagram.

The return fluid from the actuating cylinder enters the valve through the opposite actuating-cylinder connection. It flows past poppet 4 and then through the reservoir return port.

By opening poppets 1 and 3 and closing 2 and 4, the flow is reversed through the valve. Then fluid under pressure is directed to the opposite end of the actuating cylinder.

BALL-TYPE selector valves are used pretty generally in Navy aircraft hydraulic systems. Their purpose, use, and principle of operation is the same as the poppet-type valves. The only difference is the obvious one suggested by the difference in names. One uses a poppet to control fluid

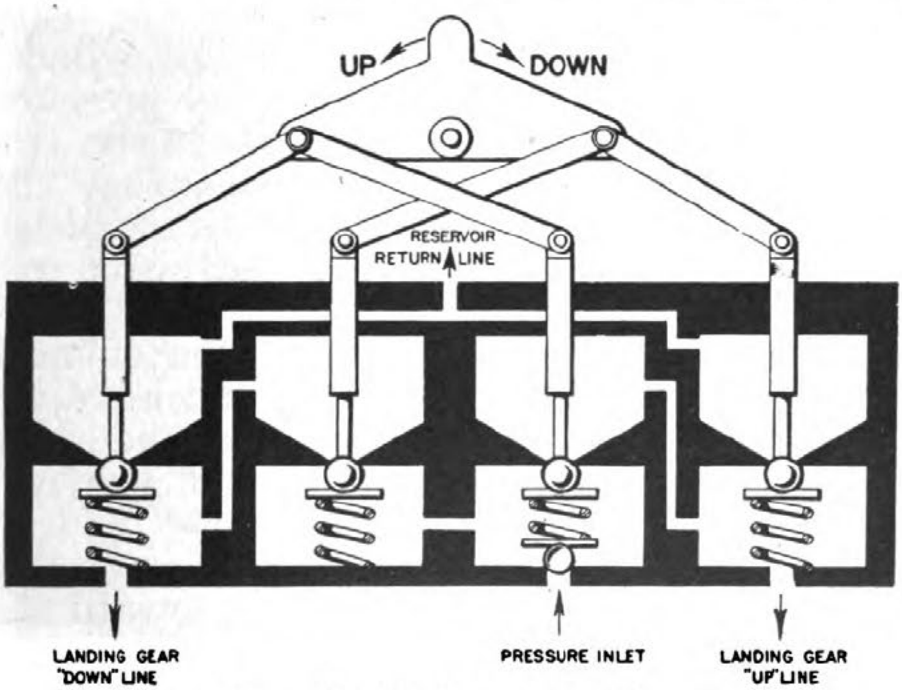


Figure 17.—Ball-type selector valve.

flow, whereas the other has a ball-shaped valve. Figure 17 gives you the story in a nut-shell.

ACTUATING CYLINDERS

SUMMING UP—you now have the hydraulic fluid being pumped through the system and its flow directed by the selector valves to and from an ACTUATING CYLINDER. But what is an actuating cylinder? What does it do?

Remember—hydraulics is never used alone to operate a mechanism. It is always necessary to use

some form of mechanical device to start or finish the operation. The actuating cylinder is that device—the part of the hydraulic system that actually imparts motion to—or actuates—the landing gear, cowl flaps, or whatever part of the airplane is moved by hydraulics.

Actuating cylinders are available in many shapes and sizes because their size and design must fit the job to be done—and these jobs vary a great deal. The principles behind the operation of all such cylinders, however, are the same.

Figure 18 shows a simple actuating cylinder that operates in both directions by oil pressure. The cylinder is closed at both ends. Inside is a piston which operates a piston rod on one end only. Seals or packings are installed on the piston and in the cylinder end around the piston rod to prevent the fluid from leaking.

Ports opening into each end of the cylinder allow the hydraulic fluid to enter and leave the cylinder. These ports alternate as inlet and outlet ports, depending on the flow to the cylinder from the selector valve.

In the top view, fluid under pressure enters the left-hand port and forces the piston toward the right-hand end of the cylinder. The motion of the piston is transmitted to a movable object by the piston rod. As the piston moves forward in the cylinder, it pushes ahead of it—and out of the cylinder by way of the right-hand port—any fluid that is in the forward end of the cylinder. This fluid is carried back to the reservoir by the return lines.

Now, if you change the setting of the selector valve, the pressure line becomes the return line and, vice versa. Then fluid ENTERS the forward end of the cylinder and the piston moves backward. As it does this, the piston shoves the fluid out of the back end of the cylinder.

By varying the diameter of the piston, the force applied to the device to be operated can be varied. Therefore actuating cylinders are made in various diameters depending on the force desired. The length of the cylinder depends on the required amount of movement of the part that is to be operated.

Another type of actuating cylinder is the single-action or spring-return type. This type has only one fluid port which is located near one end of the cylinder.

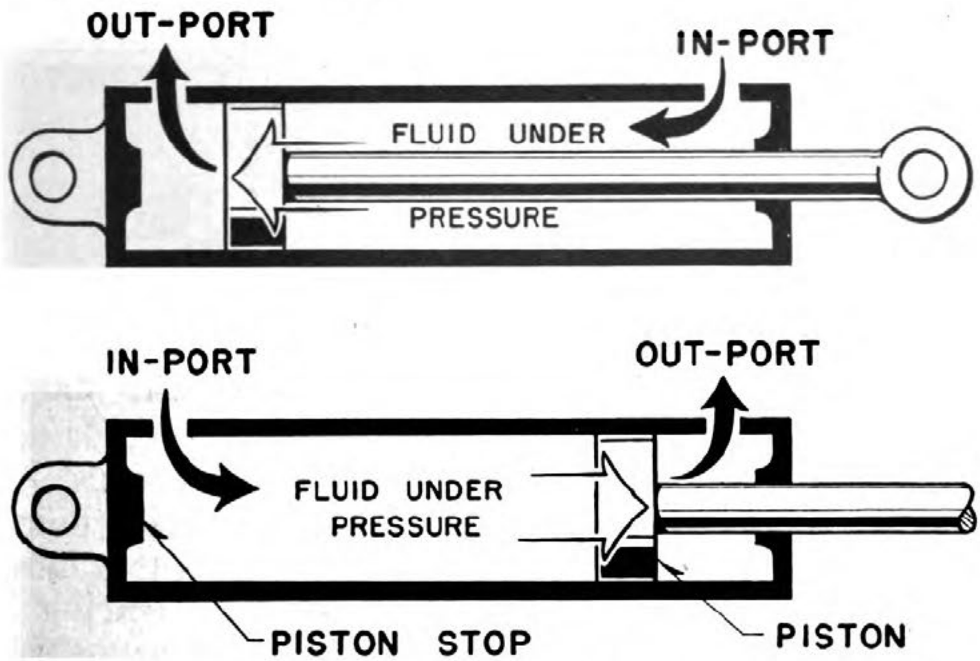


Figure 18.—Simple actuating cylinder.

The side of the piston opposite the fluid port is open to the atmosphere but is in contact with a coil spring. When fluid is introduced into the cylinder through the port, the piston moves toward the end of the cylinder opposite the port and compresses the spring. When the fluid pressure is released, the spring expands and returns the piston to its original position. Fluid is forced through the port and back to the reservoir by the return travel of the piston.

A PISTON TYPE hydraulic MOTOR looks exactly like the Vickers piston pump.

It operates like this.

Fluid under pressure is introduced into either of the two ports in the pump body depending on the setting of the control valve. The other port (as with the actuating cylinder) becomes the return port.

If the fluid flows through the motor in one direction, the motor drive shaft turns one way. If the fluid flows through in the other direction, the drive shaft turns the opposite way. The mechanical unit that is being operated turns in the same direction as the drive shaft.

The gear-type hydraulic motor is illustrated in figure 20.

It operates like this.

The pressure fluid enters at one port, operates the gears, and exits from the other port. The gears rotate according to the direction from which fluid enters. The more fluid sent through the pump, the faster the gears move.

An inspection of figure 20 shows you that the construction of the gear-type motor is similar to that of the gear-type pump. However, THE BODY OF THE MOTOR IS DIFFERENT FROM THAT OF THE PUMP IN ONE IMPORTANT DETAIL.

In the body of the motor there are two cored passages leading from each port to openings in the gear case diagonally opposite the port. Consequently, the pressure fluid contacts the gears at two points directly opposite each other instead of at just one point. This provides a balancing pressure on both sides of each gear and gives smoother performance, eliminating thrust action and stalling.

If the way this split flow operates isn't entirely clear to you after looking at figure 20, imagine that there's a clock face on each of the gears.

Then you could say that the incoming fluid hits the upper gear teeth at 7 and 2 o'clock and the lower teeth at 11 and 5 o'clock. The return fluid leaves the upper gear teeth at 5 and 11 and leaves the lower one at 2 and 7.

This type of motor delivers power in either direction of rotation and at various speeds within its minimum and maximum limits.

CHAPTER 3

SECONDARY UNITS

RELIEF VALVES

Now that you are acquainted with the primary units of the aircraft hydraulic system, the next step is an introduction to their fellow workers. First there's the RELIEF VALVES.

Pressure-relief valves are placed in the hydraulic system to keep the pressure at the predetermined value and to control it when it threatens to get out of hand. The relief valve is really a safety valve that protects the system from damage which might be caused by a pressure that is too high.

Several types of hydraulic pressure-relief valves are in general use in aircraft hydraulic systems. In each case, the basic design involves a spring-loaded valve arranged so that it automatically opens to relieve the system pressure when the fluid pressure acting on one face of the valve becomes sufficient to overcome the spring pressure applied to the opposite face.

The relief valve closes immediately when the pressure drops to a value less than the spring loading.

Figure 21 shows a typical BALL-TYPE RELIEF VALVE. It employs a spring-loaded ball resting on

a hardened-steel valve seat inside a housing. An adjusting screw is installed so that the spring pressure can be varied and the operating limit of the relief valve regulated.

The valve is enclosed in a valve body containing integral inlet and outlet bosses and a valve seat.

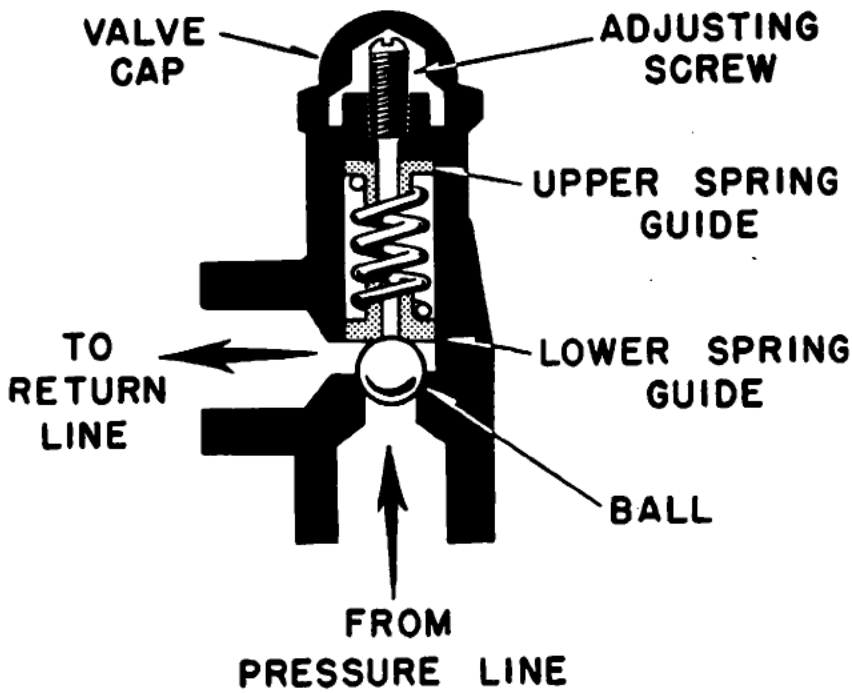


Figure 21.—A ball-type relief valve.

A highly polished hardened-steel ball is held on the valve seat by a steel coil spring. This valve is held between two spring guides which are in the form of metal disks and have integral bosses which slip inside the spring ends. One of the spring guides bears on the ball while the other is in contact with the adjusting screw in the upper end of the relief valve.

The valve body is internally threaded at its upper end to receive a bushing that carries the adjusting screw and locknut. An aluminum-alloy dust cap encloses the adjusting screw.

In figure 22 you see a typical POPPET-TYPE RELIEF VALVE. It is contained in an aluminum-alloy

body. Two ports are located at right angles to each other at the lower end of the body.

The poppet is made of steel and has a hollow machined guide with three equally spaced drilled holes. It moves in and out of a bronze valve seat pressed into the body just above the two ports and is controlled by a helical spring. One end of the spring rests on the valve shoulder while the other is contained in a hollow adjusting screw, which screws in and out of the upper end of the valve body.

A valve stop, consisting of a square steel pin with a key across one end, is installed within the

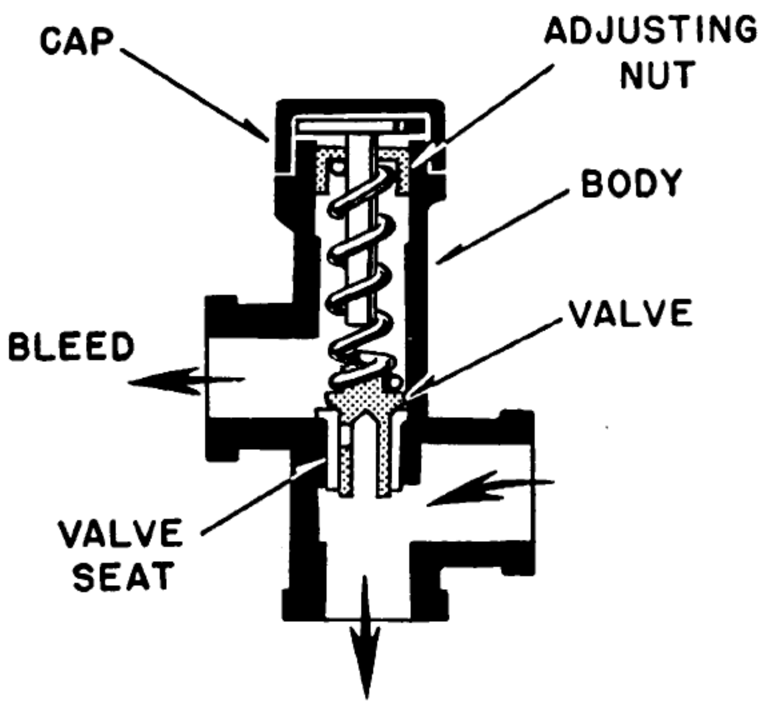


Figure 22.—Poppet-type relief valve.

spring to prevent the valve from being forced out of the valve seat in case of excessive bypass. The square pin passes through a square hole in the adjusting screw and may be drawn out to be used as a key for altering the spring tension.

When proper adjustment is made, the ends

of the key fit into notches in the end of the body to lock the adjusting screw in position. A cap screws over the end of the body to keep the valve stop in place and to prevent oil from leaking from the valve.

In this valve, when the discharge pressure exceeds the pressure setting of the relief valve, liquid enters the hollow section of the poppet from below and forces it out until the three holes pass the end of the valve seat. The liquid then flows out of the port on the side of the valve body above the valve seat. When the fluid is thus relieved, pressure decreases to a point where it is insufficient to overcome the tension of the control spring and the valve closes.

BALANCED RELIEF VALVE

The balanced-type relief valve, as illustrated in figure 23, has the advantage of smooth operation because it operates without the chattering effect produced by the ball-type valve. It operates in this manner—

Fluid from the pump enters port *A* and leaves through port *B* to enter the system. In the meantime, however, some of the fluid also goes through the metering hole *C* into the upper chamber and finds its way to the spring-loaded ball *D*. When the pressure reaches a predetermined value, it overcomes the spring *E* and unseats the ball *D*. As the ball unseats, the fluid rushes past metering hole *C* and pressure is applied to the area of *H*. But—because the hole *C* is small—the hydraulic pressure reacts upward on *H*, moves it in the same direction, and at the same time unseats valve *G*. When this valve is unseated, the fluid from the pump is permitted to flow freely to the reservoir. When the spring *E* overcomes the oil pressure, ball *D* reseats and spring *L* assists *H* and *G* to return to their original positions. This

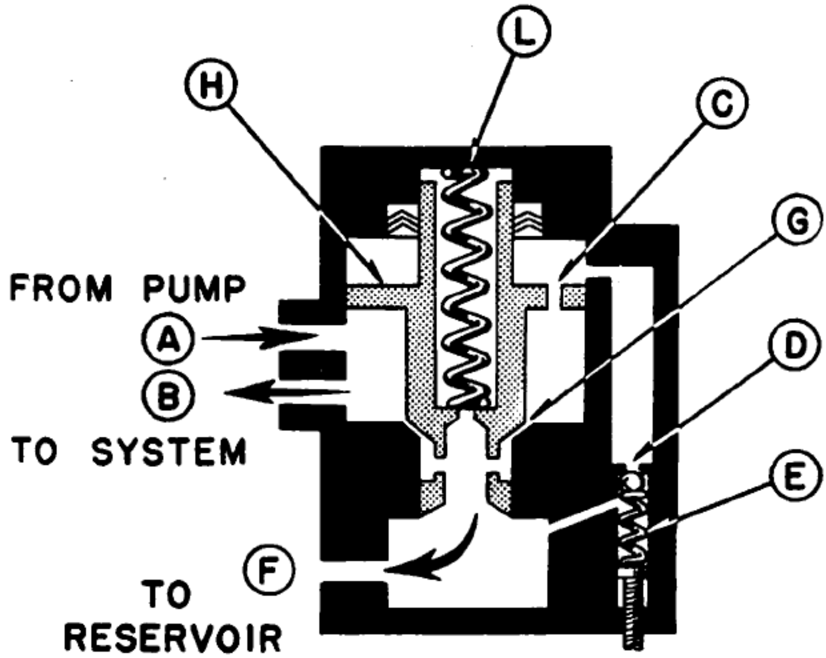


Figure 23.—Balanced-type relief valve.

permits the pressure to build up in the system again.

FLAP RELIEF VALVES

Flap relief valves are used as safety valves to prevent excessive stresses being placed on the aircraft structure if it is operated at high speed with the flaps lowered.

There are various types of flap relief valves in use on Naval aircraft. In one type, the increase in fluid pressure caused by excessive force operating on the flap surfaces causes a spring-loaded valve to lift from its seat and open a passage to the system return line.

In another type, the flap-operating strut is spring-loaded to allow the flap to be moved up when the forces acting on the flap are increased. When this takes place, a linkage opens a bypass valve to the system return line thus allowing the flap to raise. Figure 24 shows a wing-flap circuit employing this type of relief valve.

In the circuit, the flap-operating shaft is spring-loaded. At lower speeds, the tension of the spring is sufficient to retain the flaps in the DOWN position.

As the speed of the airplane is increased, the force acting on the flap surfaces is also increased. Air pressure then raises the flap against the spring tension.

When this happens, a pin in the bypass valve

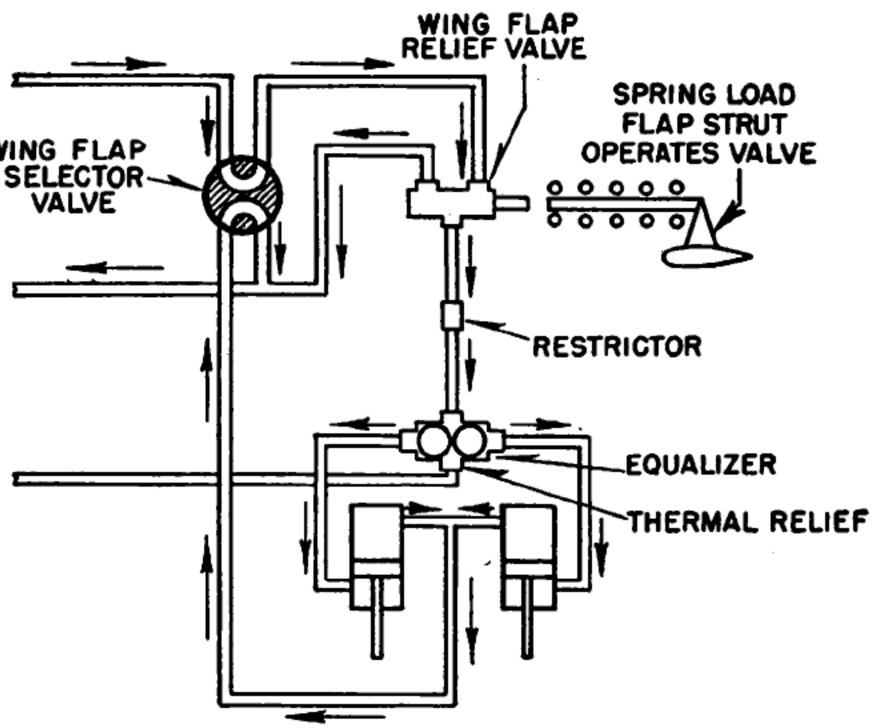


Figure 24.—Wing-flap circuit with flap relief valve.

is operated. It opens the valve to allow fluid to flow to the system return line and relieve the oil pressure in the flap actuating cylinder.

Air forces acting on the flap surfaces can then continue to force the flap upward without straining the structure, as it would be strained if the air were trying to force it up against hydraulic pressure.

As the force acting on the flap is reduced by reduction in airplane speed, the bypass valve is

closed by action of the spring lowering the flap. With the bypass valve closed, fluid pressure acts to lower the flaps again, provided the flap selector valve has been left in the DOWN position.

PRESSURE REGULATOR

The pressure regulator is first cousin to the relief valve. It operates much like a relief valve

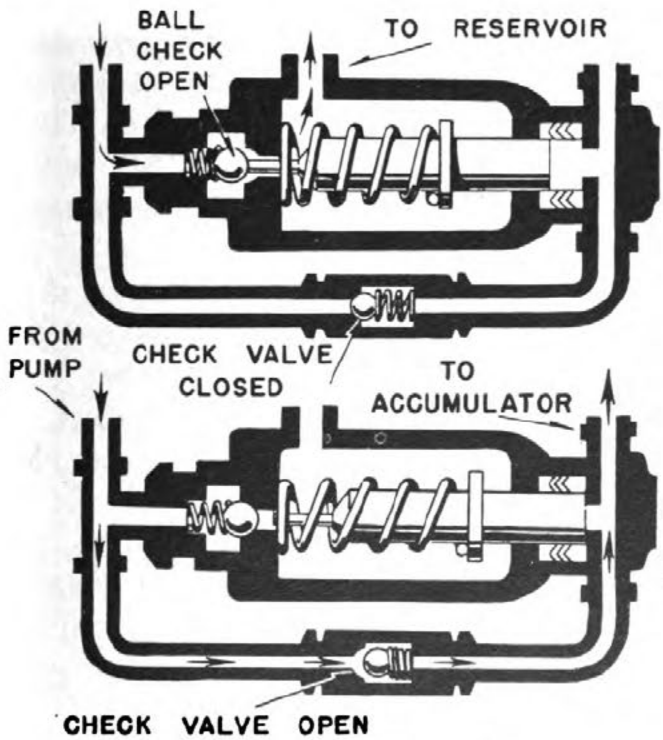


Figure 25.—Sectional view of pressure regulator.

but its control of pressure covers a much wider range. Its main purpose is to relieve the pump of its load when the system is not in operation.

As its name suggests, the pressure regulator is a device for regulating the pressure in the system. It is placed between the power pump and the system so as to bypass the oil just as soon as the system pressure reaches the upper limit of the pressure range for which the regulator is adjusted.

When that pressure value is reached, a valve in

the pressure regulator opens. The output of the power pump, which has until now been flowing into the system beyond the pressure regulator, no longer can pass the regulator and is shuttled from pump to reservoir, to pump, to reservoir, to pump, to reservoir.

This bypass circuit through the regulator continues until the pressure in the system reaches the lower limit of the range for which the regulator is adjusted. Then the valve closes, and the output of the pump is once more sent past the pressure regulator and on into the system.

The pressure regulator can be set to pass fluid into the system over a broad range of pressures.

In figure 25, you see two views of a pressure regulator. This regulator consists of several chambers with a check valve at one end of the housing and a piston at the other end. Between the two is a bypass chamber. At one side of the regulator is a shunt line with a check valve.

Fluid enters the valve end of the unit from the power pump. In the upper diagram, you can see how the fluid moves. The spring-loaded check valve in the bypass line being closed, and the piston-operated ball-check valve in the regulator being open, the fluid moves through the regulator unit. From there, it goes on into the reservoir.

As pressure builds up in the system—and in the pressure regulator also—this pressure starts acting on the piston in the regulator. Little by little, the increasing pressure moves the piston inward and the pressure-regulator valve begins to move away from its seat into a cut-out stage.

The check valve in the shunt line prevents the fluid under pressure in the system from escaping through the open valve and bypass. The valve remains open and the output of the pump is

circulated freely to the reservoir as long as the pressure in the manifold is sufficient to hold the valve in the open position.

In case the pressure in the manifold drops below the lower limit of the pressure range for which the regulator is adjusted, spring pressure on the valve and piston overcomes the lessened hydraulic forces acting on the piston. Then the valve closes and the output of the pump is again directed into the pressure manifold, as shown in the lower diagram of figure 25.

ELECTROL UNLOADER VALVE

Actually a regulator, the electrol unloader valve has three ports—a SYSTEM port, an ENGINE PUMP port, and a RETURN port.

Study figure 26 for a moment. When the regu-

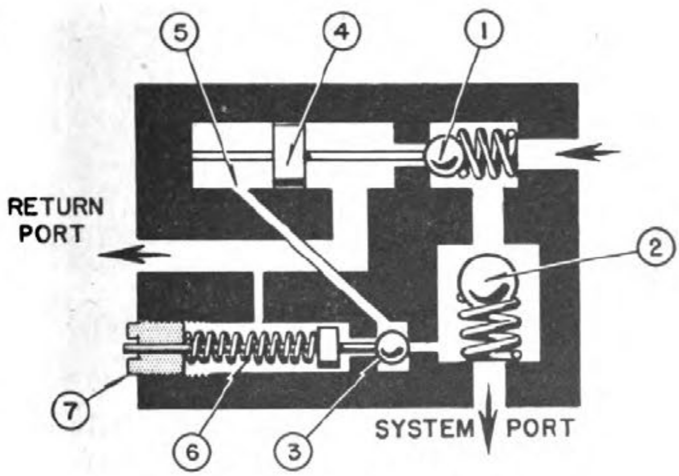


Figure 26.—Electrol unloader valve.

lator is in the cut-in position, as you see, Ball 3 is seated on the small area hole. There is no pressure in Chamber 5 to cause Piston 4 to unseat Ball 1. The flow of fluid is, therefore, from the pump port through Check Valve 2 and into the system.

When the cut-out setting is reached, the pressure on Ball 3 is sufficient to overcome the force

exerted by Spring 6. Ball 3 transfers from the small area seat to the opposite seat, the area of which is greater. When Ball 3 transfers, system pressure is permitted to act on Piston 4 which unseats Ball 1, allowing the flow of fluid to be directed to the return port.

The system pressure acts on Check Valve 2, seating it to prevent the loss of system pressure back through the regulator. When the system pressure drops to the cut-in setting, the tension of Spring 6 overcomes the pressure on Ball 3, and Ball 3 transfers to the small area hole. This transfer allows the pressure trapped in Chamber 5 (behind Piston 4) to escape through Chamber 6 into the return port. Ball 1 then seats and closes off the return flow of fluid. The flow is then directed through Check Valve 2 into the system.

The only practical ADJUSTMENT is that which can be made by tightening or loosening Nut 7. This adjustment will raise or lower the cut-out setting, which raises or lowers the range. No pressure differential adjustment is possible. The area of the seats for Ball 4 determine the differential between the cut-in and cut-out pressure.

VICKERS PRESSURE REGULATOR

The Vickers pressure regulator comes in two basic designs—one with an internal drain and one with an external drain. However, the EXTERNAL DRAIN design is the one that concerns you most in Naval Aviation.

When the regulator is in the cut-in position, as you see in figure 27, the flow is from the pump port through Check Valve 2 into the system. When the system pressure reaches the cut-out setting, pressure acting upon Plunger 5 overcomes the tension on Spring 6, moving Pilot Spool 1 upward.

Pilot Spool 1 then directs fluid under pressure to the left end of Directional Spool 4, and the

fluid moves this spool to the right. At the same time, the movement of Spool 1 provides an escape for fluid from Spool 4 into Line 8, which forces Unloading Spool 3 from its seat. This permits a free flow of fluid between the engine pump and the return port. Check Valve 2 closes to prevent the system pressure from escaping back through the regulator to the reservoir. When the system pressure drops to the cut-in setting, Spring Tension 5

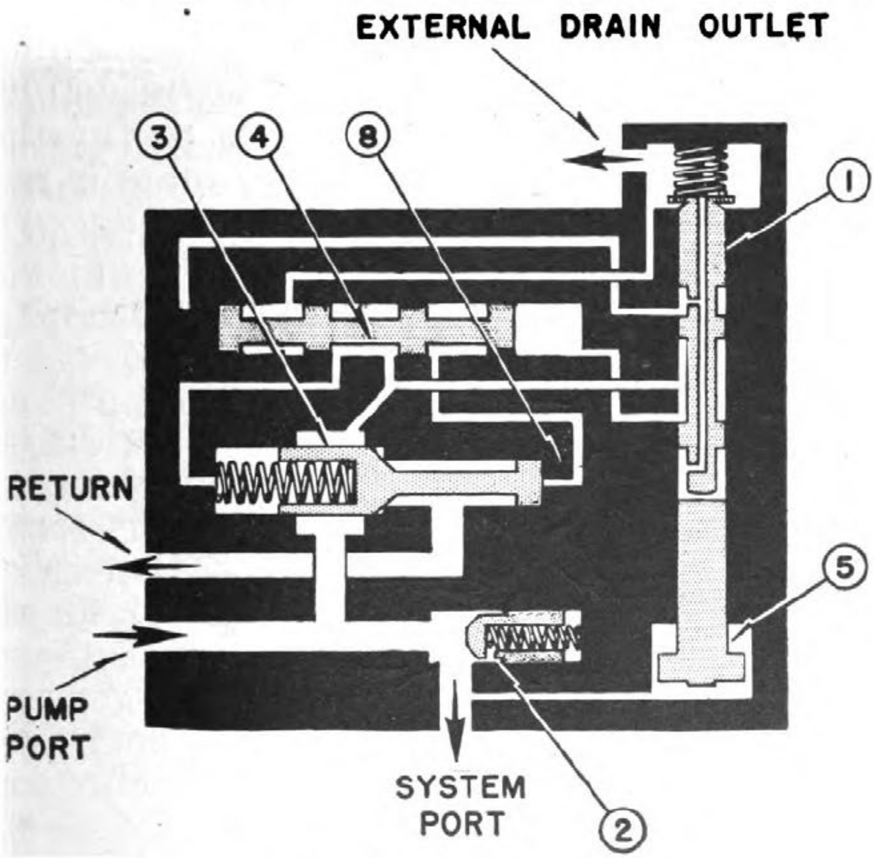


Figure 27.—Vickers pressure regulator.

forces Pilot Spool 1 down. This causes the reverse action to occur and the regulator again cuts-in.

The Vickers pressure regulator has no external adjustment. To raise or lower the range, shims must be added or removed under Pilot Spring Valve 6. The pilot valve spring is made accessible by removing the pilot spring cap.

While the "pressure" is on, take a look at another member of the hydraulic system—the PRESSURE ACCUMULATOR or PRESSURE TANK.

The accumulator stores fluid when demands of the system are low. Then, when the capacity of the pump is insufficient to do all the work required of it, the accumulator feeds its reserve stock of fluid to the system units and keeps things going.

Not content with performing this valuable duty, the accumulator also serves as a source of hydraulic power when the pump fails to function and emergency operation of certain units is nec-

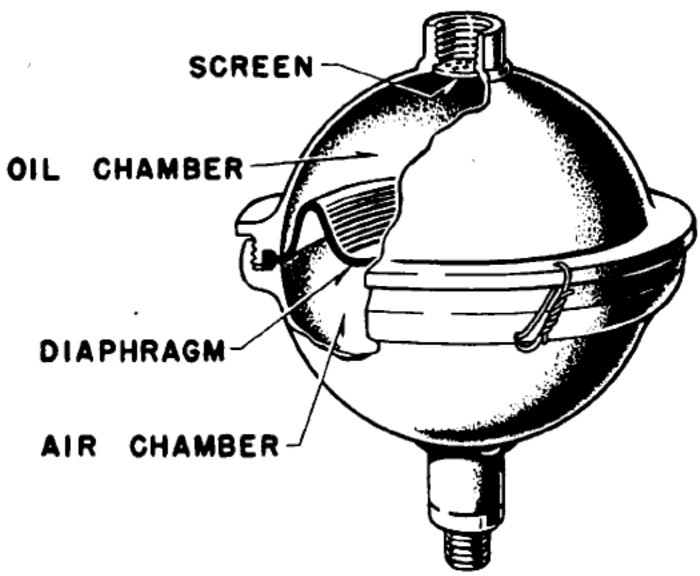


Figure 28.—Pressure accumulator.

essary. In its spare time, the accumulator acts as a surge chamber to prevent sudden surges of fluid pressure from damaging the system.

Actually, a pressure accumulator serves much the same purpose in the aircraft hydraulic system that the storage battery serves in the electrical system.

A spherical hydraulic-pressure accumulator,

with a section of the outer shell removed, is shown in figure 28. This accumulator is made up of two forged steel hemispheres which are screwed together to form the complete sphere. The halves are separated by a rubber diaphragm thus forming two chambers. The upper chamber is the fluid chamber and is connected to the fluid supply line at a point close to the unit it is to operate. The lower half of the accumulator is the air-pressure chamber and is fitted with an air valve (similar to the valve on automobile tires) for charging the chamber with compressed air. Air is pumped into the chamber at a pressure specified for each installation.

With the accumulator in the charged condition and the fluid chamber empty, the diaphragm is forced against the walls of the fluid chamber by air pressure. The introduction of fluid into the fluid chamber causes the diaphragm to be forced towards the walls of the air chamber. This further compresses the air charge and increases the pressure.

When the fluid pressure in the line to which the fluid chamber is connected drops below the pressure of the air in the accumulator, the air expands and forces the diaphragm towards the fluid-chamber walls. This forces fluid from the accumulator into the system.

The accumulator again becomes charged with fluid during periods when the demands of the system do not require the full output of the engine pump.

Figure 29 illustrates another type of accumulator used in aircraft hydraulic systems. In this accumulator, the housing or shell is a hollow steel cylinder with rounded ends. This housing has an opening for the valve stem at its upper end and a boss for the attachment of system tubing at its lower end. The air chamber in this type of ac-

cumulator is an elastic bladder fitted with an air valve and inserted into the cylinder. The air valve extends through the upper end of the accumulator body and is locked in place by two nuts and a washer.

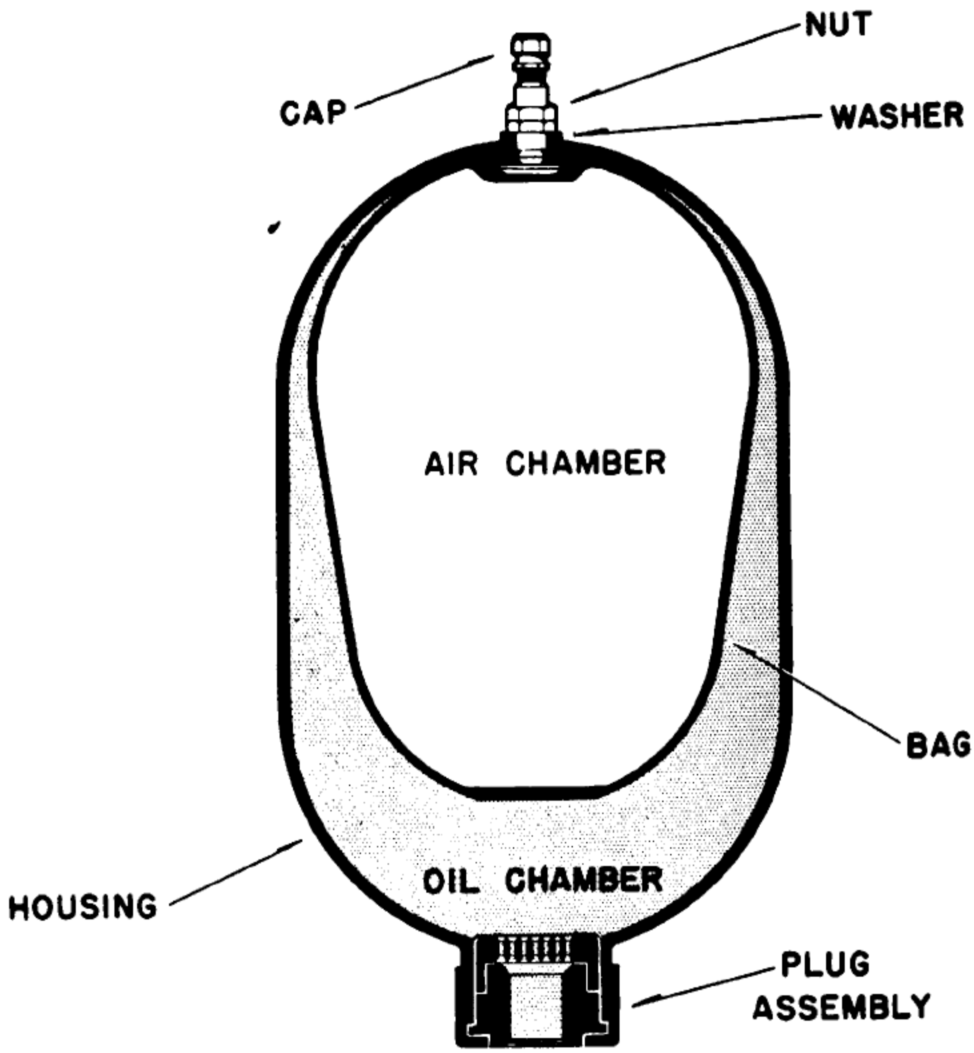


Figure 29.—Another type of pressure accumulator.

It is frequently necessary for the mechanic to check the accumulator.

One check is made with the main system pressure gage. You place all selector valves in "neutral" position. Place the hand pump control valve in such a position that the flow from the hand

pump will go into the accumulator. Then pump the hand pump two or three strokes.

The gage will immediately jump to the pre-load setting of the accumulator. The pressure recorder on the gage, at the moment when it stops rising rapidly, indicates the pre-load pressure in the accumulator.

Another method involves building up system pressure in the accumulator by use of the hand pump or the engine driven pump, depending on the design of the system. Make sure that the gage records the pressure in the accumulator. Then bleed the system pressure off slowly (no pumps should be operating) by actuating some small unit such as the cowl flaps. The pressure recorded by the gage just before it drops abruptly to zero indicates the air pre-load pressure in the accumulator.

In relieving the air pre-load pressure in an accumulator, it is important that the mechanic NEVER depresses the valve core. The great pressure differential between the inside and the outside of the accumulator would rupture the air valve core. The proper procedure in allowing the air pressure to escape is to unscrew the air valve fitting approximately two revolutions.

Here's a tip—

In replacing air valve cores, use a high pressure core of the recommended type.

SURGE CHAMBERS

Surge chambers, like the one diagrammed in figure 30, are used in the aircraft hydraulic system for lessening the effects of pressure surges. They are small, hollow cylinders containing an inflatable bladder. They are installed in the pressure side of the hydraulic system and are used usually in conjunction with a power-control valve or pressure-relief valve.

In operation, sudden increases in hydraulic fluid pressure are absorbed by compression of the air in the bladder. As the system pressure becomes less, the compressed air expands, thus maintaining a more nearly even pressure. In some models of surge chambers, the inflatable bladder is replaced by a spring-loaded piston.

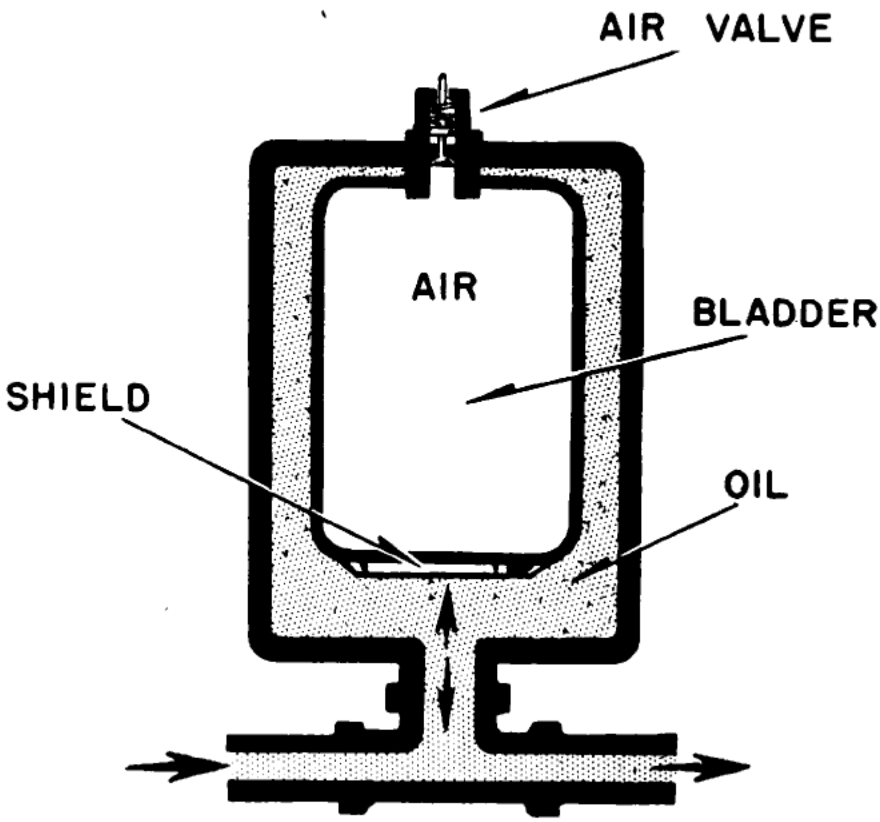


Figure 30.—Surge chamber.

Actually, surge chambers are similar to accumulators except that they do not store up a great amount of power.

FILTERS

The filter (or strainer) stands guard at the reservoir to prevent any sabotage of the hydraulic fluid. Bits of metal, dirt, and other enemy aliens are taken in hand and held in a concentration camp for ultimate disposal.

Pictured in figure 31 is the MESH-TYPE FILTER. It has a housing, filter element, scraper, and plug.

The filter element is a fine-mesh screen. This element is the part that collects particles of foreign matter that may be in the oil. If these weren't screened out, they might jam a valve seat open or do other damage.

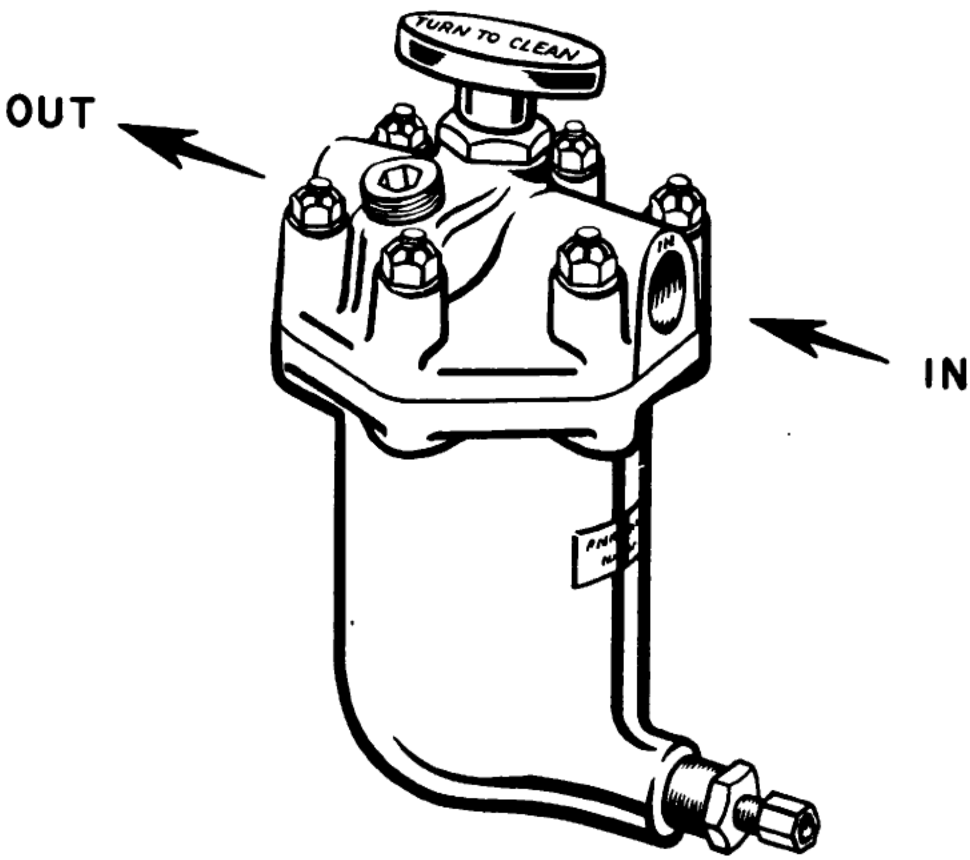


Figure 31.—Mesh-type filter.

The scraper is similar to the kind of gadget housewives use to scrape the food off dinner plates before washing them. Its job is to remove sludge from the surface of the filter element.

The removable plug permits removal of the sludge from the filter.

In this filter, the fluid passes through the IN port in the housing to the outside of the filter element. It then passes through the openings in the filter element from OUTSIDE to INSIDE and

leaves the filter by the OUT port. As the fluid passes through the filter element, sludge or foreign particles collect on its outside surface.

The element is cleaned by rotating it by the handle at top. A stationary scraper which bears against the outer surface of the element removes all sludge and foreign particles, which drop to the bottom of the filter housing. They are removed by taking out the clean-out plug at the bottom. The filter is disassembled easily for periodic cleaning in a solvent.

Figure 32 illustrates an EDGE-TYPE FILTER. In this filter, the foreign matter is removed from the fluid when it passes between the surfaces of metal disks. It is then cleaned from the disks by rotating them with the handle. Cleaner blades which extend between each two adjacent rotating disks scrape the foreign matter from them and it drops to the bottom of the filter. These filters are also disassembled periodically and washed in a solvent.

Both types of filters illustrated have integral bypass valves which open to allow fluid to pass if the filter element is clogged. This condition will not occur, however, if the filter handle is turned daily or before each flight and the filter element is cleaned regularly.

The filters are installed usually on the system return line and that is the ideal location for them. Installation limitations, however, may make it necessary to install them on pressure lines. NEVER install them on pump suction lines as they will cause an excessive pressure drop.

BLEED

If you want to get technical, the bleed is really not a unit of hydraulic equipment. It is, however, an important feature on certain hydraulic units, so you ought to know how it works.

The duty of a bleed is to transfer pressure past

the seal of a hydraulic unit. It constitutes a perpetual leak in the unit and permits a slow and gradual equalizing of pressures on both sides of the seal.

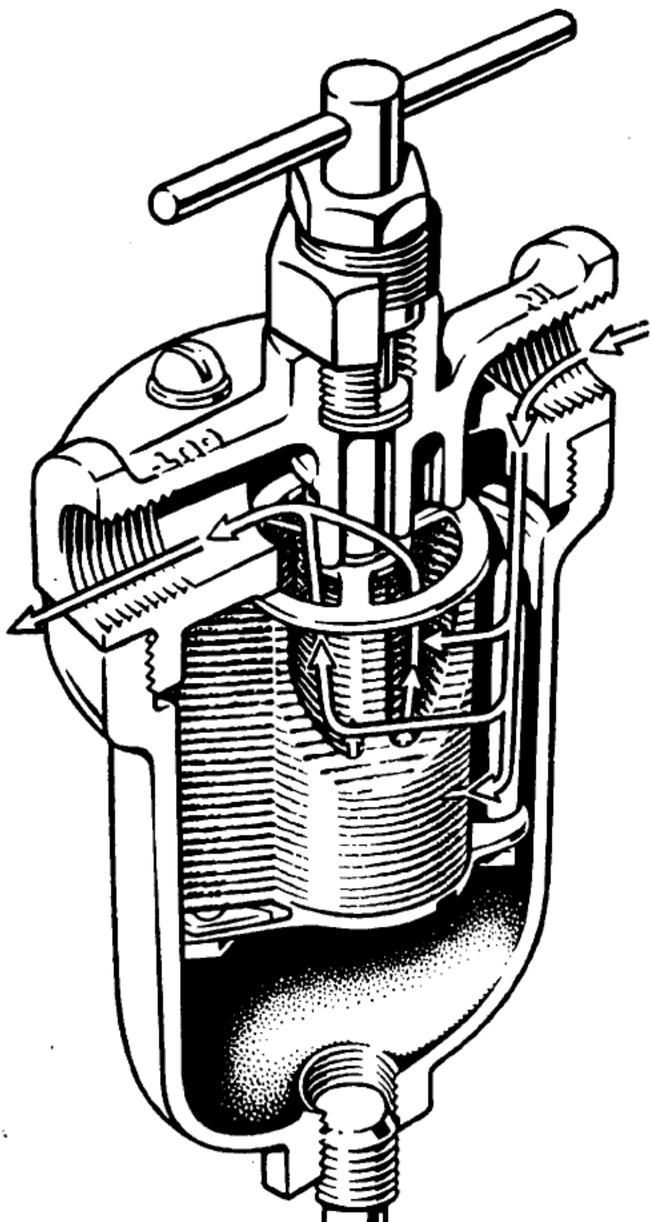


Figure 32.—Edge-type filter.

A bleed consists of an extremely small hole drilled in the unit in such a manner as to shunt fluid around the seal of the unit. If a check valve

or bypass check valve is installed in the pressure manifold of a hydraulic system, it may be provided with a bleed so that excessive pressures created by temperature expansion in the lower section of the manifold can reach the accumulator, surge chamber, or other pressure-absorbing device in the upper section of the manifold.

EXACTOR CONTROLS

Hydraulic exactor controls are used in modern aircraft to provide accurate control of apparatus located some distance away from the point of operation. With larger airplanes, the linkages necessary to control such apparatus by mechanical means become complicated. Inaccuracy due to lag and backlash increases with the distance from the point of control. Hydraulic exactor controls eliminate this difficulty.

These exactor controls operate on the principle of transmission of motion through the incompressible fluid.

The use of hydraulic exactor controls is particularly adaptable to the remote control of certain units of aircraft radio equipment, such as the directional antenna, where a high degree of accuracy is desired. They may be used also for operating the controls of engines located a considerable distance from the cockpit.

Hydraulic exactor controls consist of two units called the TRANSMITTER and the RECEIVER. They are shown in figure 33.

As installed in Naval aircraft, these two units are connected by a single line of tubing. It will be seen that the transmitter consists of a spring-loaded rocker arm connected to the operating piston. The piston is fitted into a cylinder which is connected by a valve to a fluid reservoir in the unit.

The purpose of this reservoir is to replenish

fluid lost by leakage and to compensate for changes in fluid volume caused by temperature variation. The parts of the receiver are similar to those of the transmitter with the exception of the fluid reservoir.

The cylinders of the transmitter and receiver

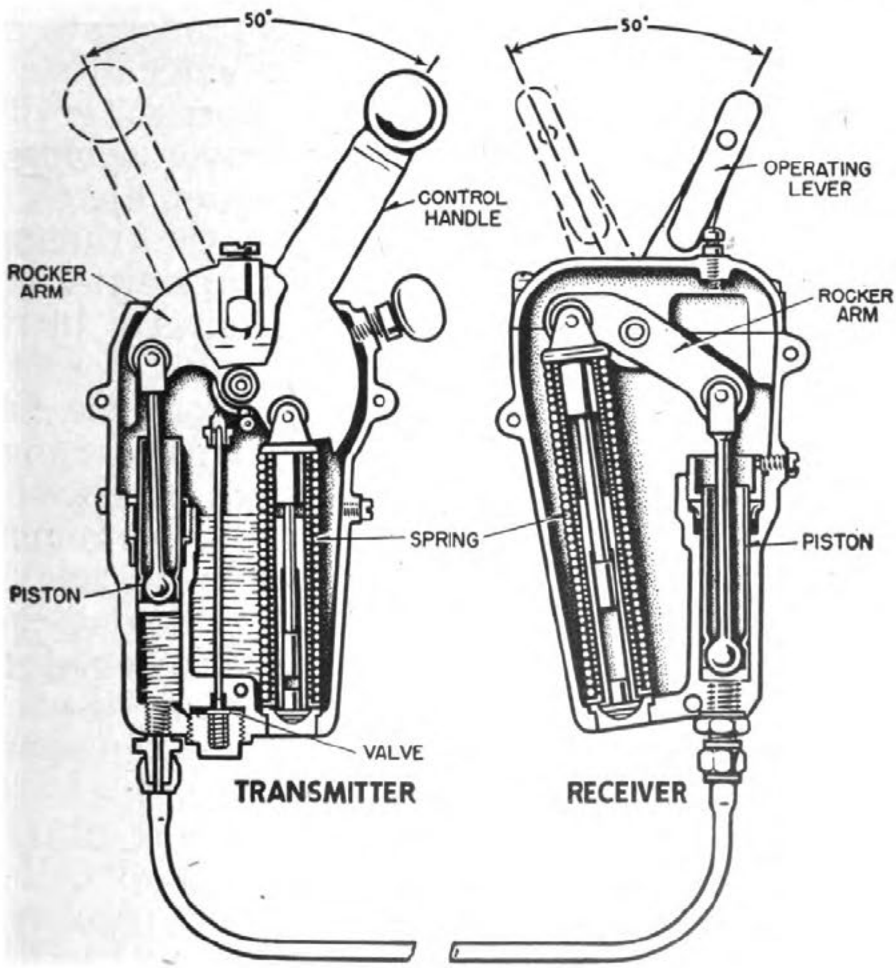


Figure 33.—Extractor control.

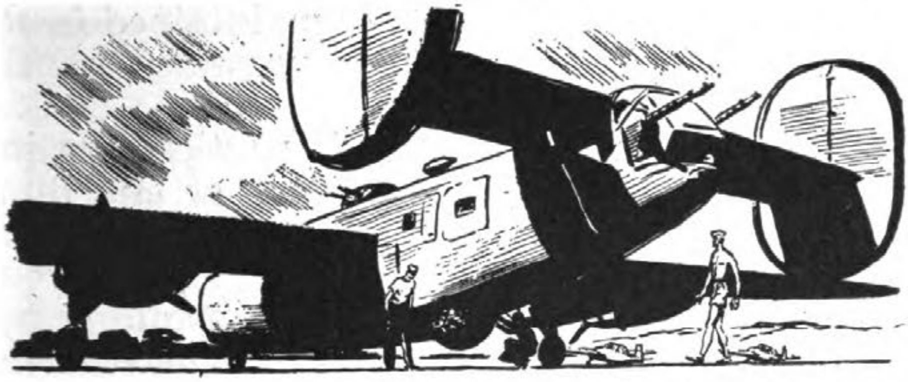
are connected by a tube, as you know. This line is filled with hydraulic fluid and forms a linkage between the two units.

As the piston in the transmitter is moved downward in its cylinder by the rocker arm and control handle, fluid is forced from the transmitter cylinder to the receiver cylinder through

the connecting tubing. This causes the receiver piston to be moved upward in its cylinder. The upward motion of the receiver piston is transmitted to the operating lever through the receiver rocker arm. The subsequent motion of the rocker arm compresses the receiver spring.

When the handle of the transmitter is moved in one direction—to the right in the illustration—it causes the transmitter piston to move up in its cylinder and relieve the hydraulic pressure. The relief in pressure permits the receiver spring to snap its piston downward. This action ejects the hydraulic fluid, which flows back to the transmitter, as shown. The motion of the transmitter control handle has been reproduced exactly by the motion of the lever of the receiver.

The linkage between the valve from the fluid reservoir and the transmitter cylinder is arranged so that, during the last few degrees of travel of the transmitter piston in moving up in its cylinder, this valve is opened and fluid flows from the reservoir into the cylinder to replenish any fluid lost by leakage or contraction. It also serves the purpose of relieving fluid pressure in the line when increased temperatures cause it to expand.



CHAPTER 4

SPECIAL VALVES

CHECK VALVES

Check valves are the S. P.'s of the aircraft hydraulic system. They are posted throughout the system ever on the alert to keep the hydraulic fluid from entering spots that are "out of bounds."

Spring-loaded ball-type and spring-loaded poppet-type check valves are encountered most frequently. The principle of operation for both types is similar and quite easy to understand.

The ball-type check valve is illustrated in figure 34. As you can see, the ball is held against its seat in the valve body by spring tension. Installed in a fluid line, the valve will remain in the closed position until the fluid pressure acting on the INLET side of the ball reaches a pressure greater than the combined spring and fluid pressure acting on the opposite side of the ball. Then—the ball leaves its seat and fluid is free to flow through the check valve in the direction indicated by arrows.

As soon as the fluid pressure on the INLET side of the ball drops below that on the OUTLET side, the spring returns the ball to its seat and prevents fluid from flowing in the opposite direction.

In this way, fluid pressure is maintained in the portion of the system that is protected by the check valve.

In hydraulic lines where it is particularly important to prevent the reverse flow of any fluid, a DOUBLE ball-check valve is used. Take a look at the one illustrated in figure 35.

This valve has the same effect as installing two separate check valves in the line. There is not much chance of both valves in the double ball-

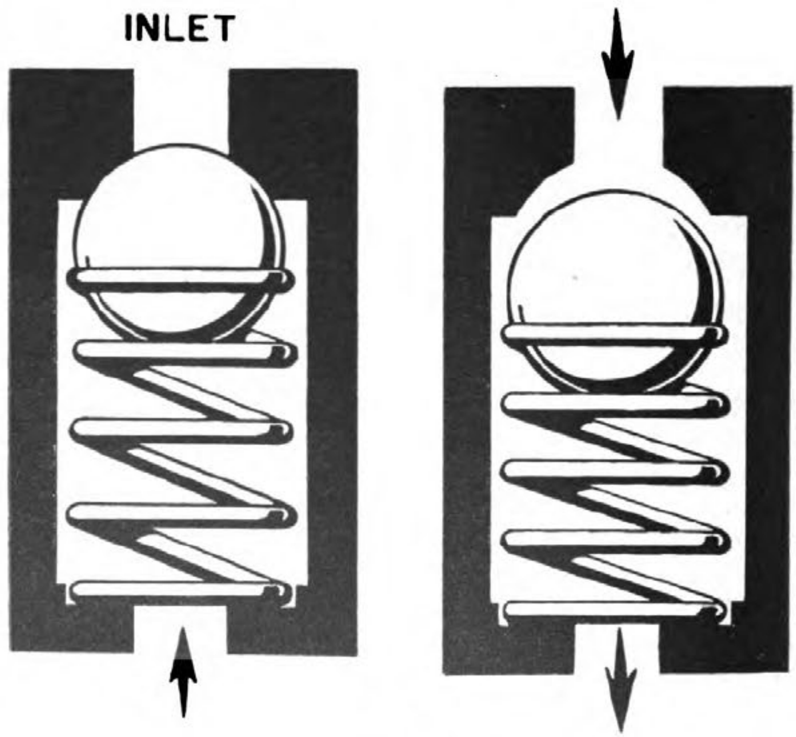


Figure 34.—Ball check valve.

check valve being held open by foreign particles at the same time and the safety factor is thus doubled.

In addition to the check valves you've already met, BYPASS check valves and ORIFICE check valves are also used in some hydraulic systems.

Orifice check valves are used in hydraulic lines when it is desired to restrict the flow in one direc-

tion only, allowing a free flow the opposite way. An orifice check valve is shown in figure 36.

You can see from this illustration that, even though the valve is in the closed position, an

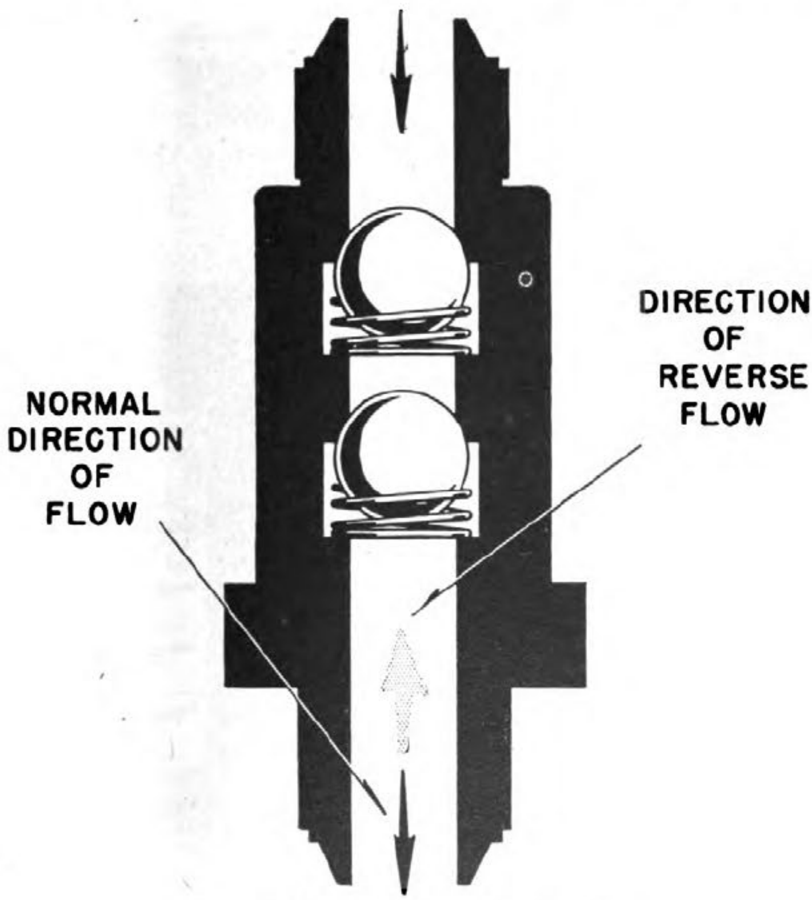


Figure 35.—Double ball-check valve.

orifice (or passage) allows a small amount of fluid to flow back through the valve. With the fluid flow in the normal direction, the valve acts in the same manner as a plain ball-check valve.

Orifice check valves are used in some wing-flap systems to keep air force from forcing the flaps up too rapidly. They are also used in some landing-gear systems to delay the extension of the gear by counter-acting the natural tendency of the weight of the gear to force it down too fast.

Bypass check valves are simply ball or poppet-

type check valves equipped with a means of mechanically lifting the valve from its seat in the housing. Figure 37 shows a schematic drawing of a ball-type bypass check valve.

You can see from this drawing that, with the control lever in the position holding the ball away from its seat, the fluid is permitted to flow through the valve. With the lever in the released position, fluid cannot flow directly through the

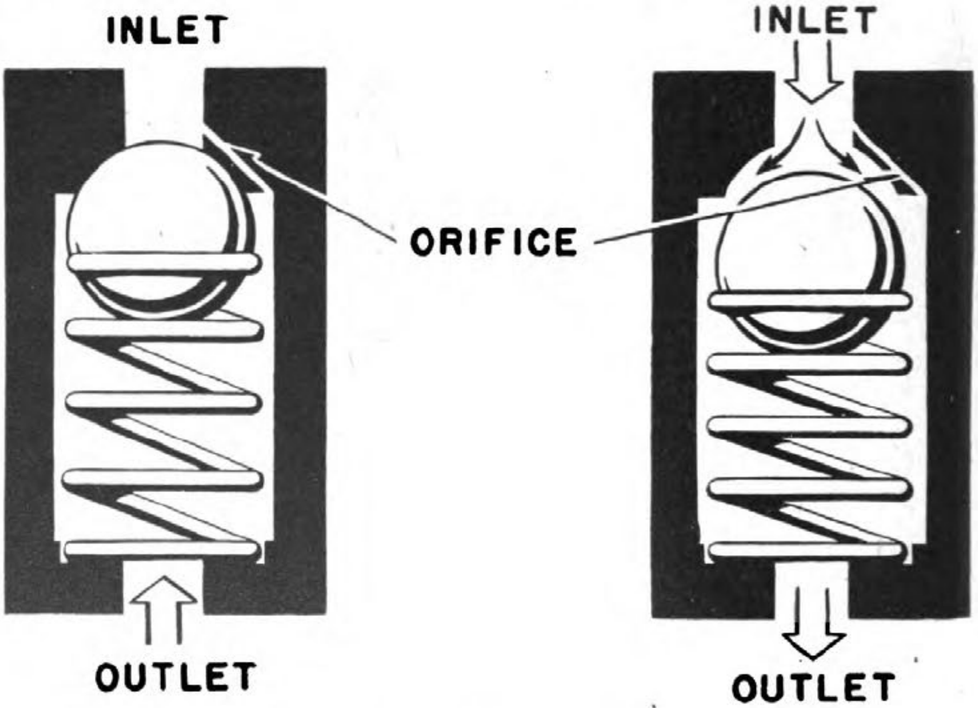


Figure 36.—Orifice-check valve.

valve but is permitted to bleed through a bypass.

There is generally a bypass check valve between the hand pump and the pressure accumulator. With the valve installed as shown in figure 38, with the OUTLET port connected to the hand-pump line, the accumulator is isolated from the hand-pump circuit when the control lever is in the released position, except for the slow equalization through the bypass.

When the pilot moves the control lever, the

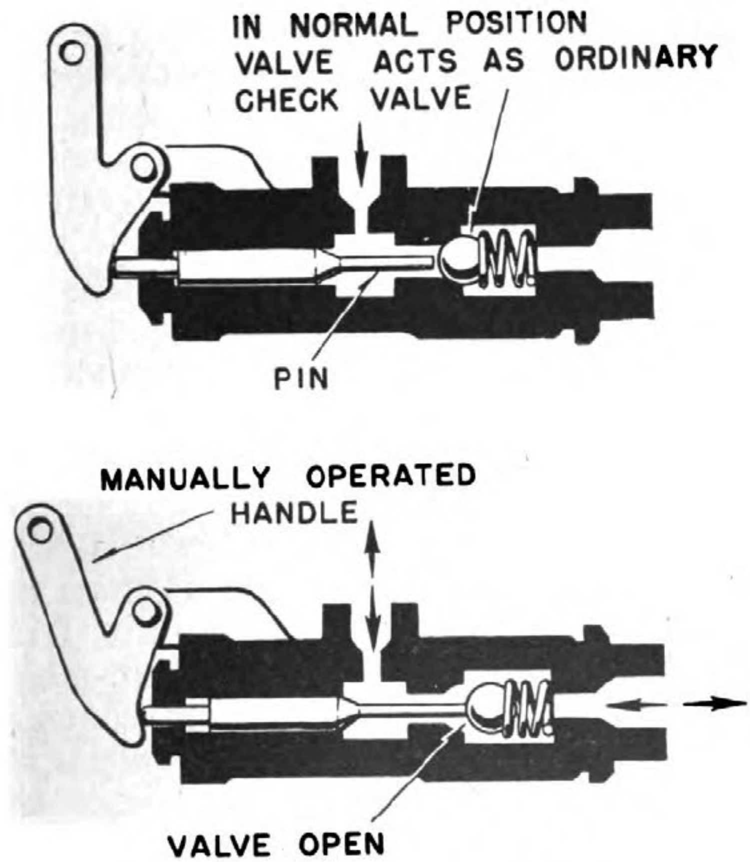


Figure 37.—Bypass check valve.

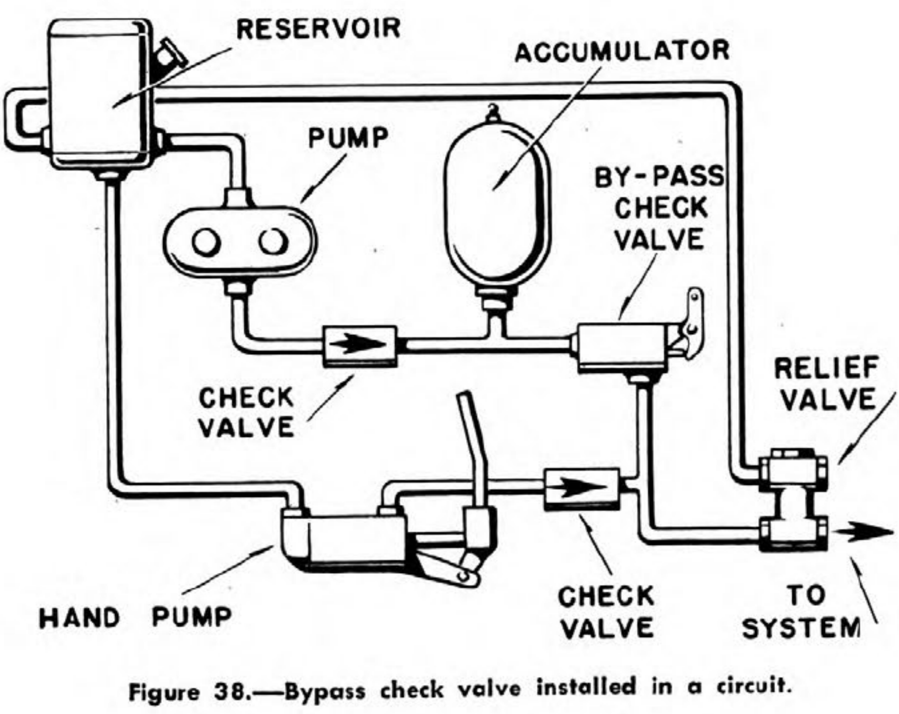


Figure 38.—Bypass check valve installed in a circuit.

valve is lifted from its seat and the line from the hand pump to the accumulator is opened. Thus, the accumulator can be charged by using the hand pump.

With the bypass check valve closed, the output of the hand pump is routed directly to the actuating circuit. The control lever for this valve is located usually in some spot where it is readily accessible to the pilot or other members of the crew.

POWER-CONTROL VALVE

The power-control valve is a "shut-off" valve that is closed by hand and opens automatically. It permits the flow of fluid to circulate from the power pump to the reservoir without making it necessary for the pump to develop continuously such high pressures as are needed to keep a relief valve open.

A power-control valve is used only in a hydraulic system that does not have a pressure accumulator.

When pressure is NOT required in the hydraulic system, the output of the power pump is directed through the power-control valve as illustrated at the top view of figure 39, and then to the reservoir.

When pressure IS required, the pilot presses a knob on the power-control valve. This causes the piston to enter the OUTLET port of the valve as shown in the lower part of figure 39, and to close the fluid passage through the unit. The fluid no longer passes through the valve but is now directed into the system where pressure builds up to operate the mechanism.

When the mechanism has been moved to the limit of its stroke, as seen in the lower view, a spring lifts a pin that locks the piston in the closed position. An excessive pressure then builds

up inside the valve cylinder. But fluid bleeds into the lock-pin chamber and the pressure forces the pin down until the piston is released. The pressure then slides the piston out of the OUTLET

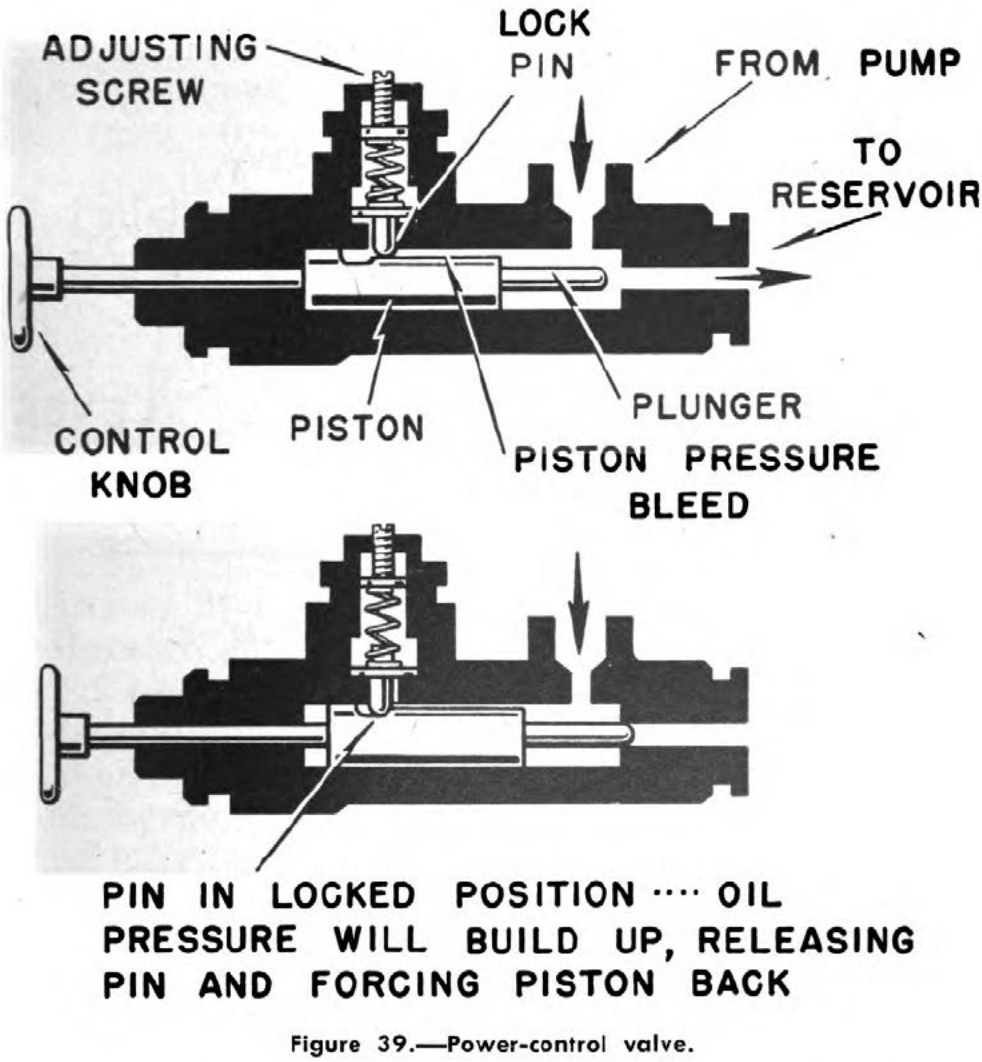


Figure 39.—Power-control valve.

port. This action opens the passage in the valve so that the fluid is free to circulate to the reservoir.

Note that the pressure at which the valve is released is controlled by the tension of the coil spring surmounting the lock pin. An external adjustment is used to regulate the tension of this spring.

Power-control valves are located usually near the selector-valve controls where they are within convenient reach of the pilot. If more than one power-control unit is installed in the airplane, they are connected in series so that—if the knob of any one of them is pushed inward—the circulation of fluid to the reservoir is shut off and pressure starts to build up in the system.

EMERGENCY UNLOADING VALVE

Emergency unloading valves are installed in the landing-gear unit so that the wheels can be

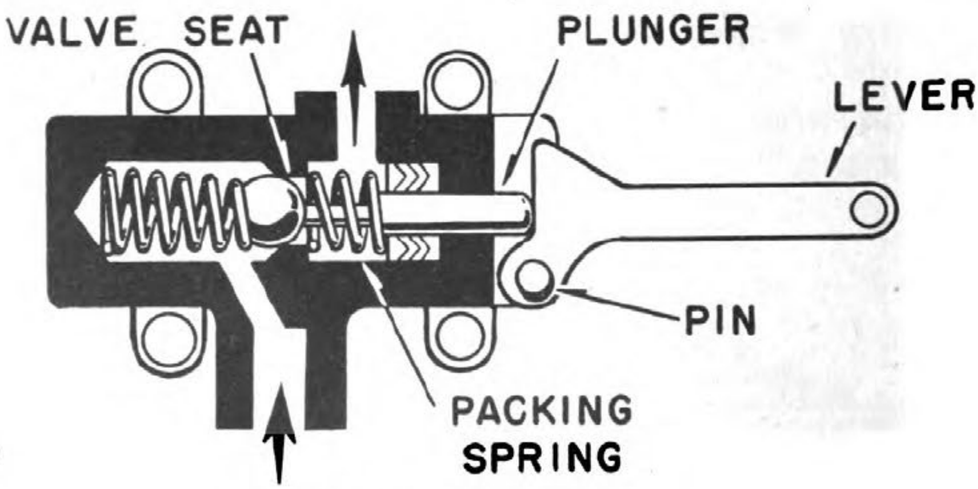


Figure 40.—Emergency unloading valve.

lowered in the event the hydraulic actuating system should fail completely. The majority of emergency unloading valves are constructed in the same general manner so a description of one pertains to them all. A typical emergency unloading valve is diagrammed in figure 40.

In this valve, an aluminum-alloy housing or body provides connections for lines leading from the selector valve to the landing-gear actuating cylinder and then back to the tank. Within this housing is a spring-loaded ball valve arranged so that the normal fluid pressure holds the ball

tightly on its seat. A plunger is located directly in line with the ball valve and is equipped with an operating lever.

The valve is operated by pushing down on the lever which acts against the plunger and forces the plunger inward. This pushes the ball away from the valve seat and permits the fluid to flow into the unloading line, upward, and back to the tank. When the UP locks of the landing gear are released and the landing gear moves downward, the fluid is free to flow overboard and restraining action is no longer applied to the gear.

EMERGENCY SHUTTLE VALVE

Another type of emergency valve in use on certain Naval aircraft is the emergency shuttle valve. This valve is used on the wing flaps, brakes, landing gear, and bomb-bay emergency systems. It consists primarily of a spring-loaded piston which controls the fluid passage to the respective actuating cylinder.

During normal operation, the spring-loaded piston covers the emergency fluid entry port. In an emergency, it is forced to cover the normal fluid entry port. One end of the valve is attached to the normal fluid entry extension line while the other end is attached to an emergency line connected directly to the hand pump, or to a nitrogen, CO_2, or compressed-air bottle.

If leakage occurs past the valve, pressure builds up in the emergency line. This pressure moves the valve over the cylinder entrance port, resulting in complete failure to retract or faulty operation of the unit involved. In the event this trouble occurs, the pressure in the emergency line can be relieved by opening the bleed valve on the emergency line and allowing the shuttle to return to its normal position.

FLOW EQUALIZER

The flow equalizer is sometimes called the FLOW DIVIDER. Strictly speaking, it is not a valve at all but it operates with the valves to control the flow of fluid through the hydraulic system.

Flow equalizers are used in aircraft hydraulic circuits to divide fluid flow equally between two units that are operated simultaneously.

If flow equalizers were not installed, any difference in resistance to movement would cause the flap having the least resistance to be lowered first. This would have a serious effect on the control of the airplane.

A flow diagram of a flow equalizer installed in a hydraulic-flap circuit is shown in figure 42.

There are two types of equalizers—PISTON type and GEAR type. Both resemble hydraulic motors in their construction.

The piston-type flow equalizer consists essentially of two piston-type hydraulic motors mounted with their shafts splined together. One port of each motor is connected to a line from the selector valve and the other port on each motor is connected to a port on the actuating cylinder that it is to control.

The shafts of the motor are splined together so that they rotate in unison. Consequently, only as much fluid can flow through one motor as can flow through the other.

A gear-type hydraulic flow equalizer is a casing containing two gears in close mesh. The gears are fitted into the casing to close tolerances and are arranged so that fluid entering the casing in either direction causes the gears to rotate. Since the space between the gears and the casing is equal for both gears, an equal amount of fluid flows between each gear and the casing.

By directing fluid under pressure to the actu-

ating cylinders in one direction, fluid enters the equalizer through the upper port and is directed to the actuating cylinders through the two side ports. Under these conditions, the gears rotate in the direction in which the gears separate at the point nearest the upper port. Operation of the

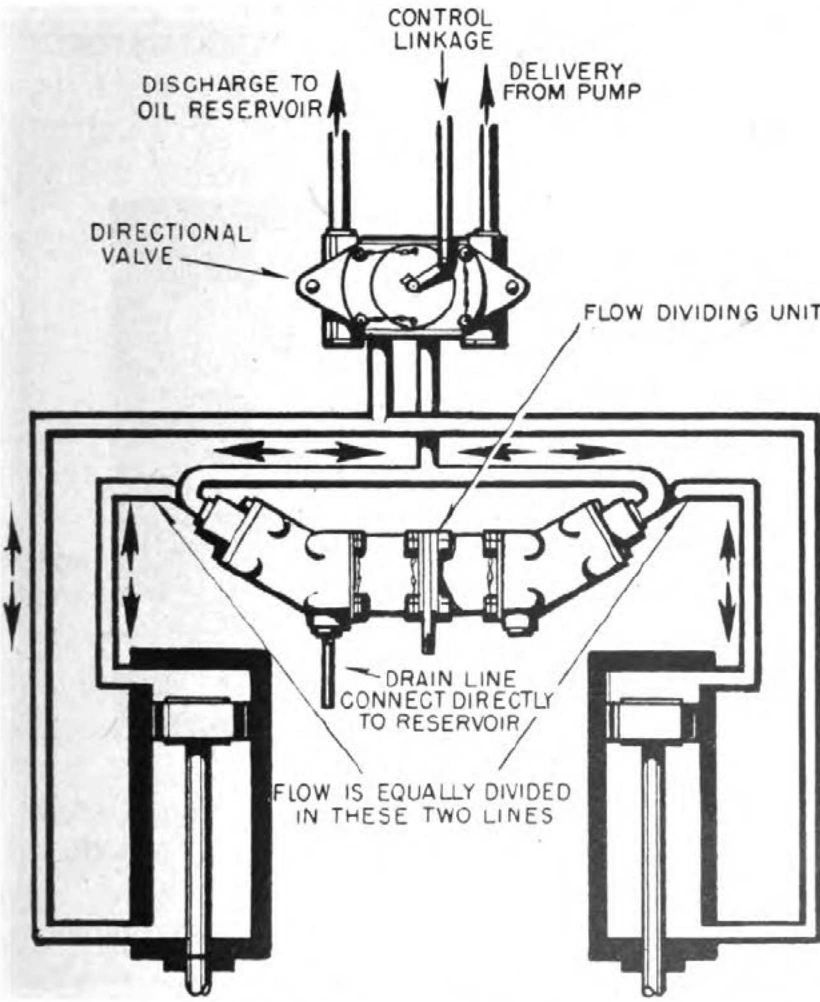


Figure 41.—Piston-type flow equalizer.

cylinder in the opposite direction causes the fluid to enter the equalizer through the side ports and flow to the selector valve through the upper port. The gears then rotate in the opposite direction.

In most cases, flow equalizers work accurately in one direction only. For instance, they make it possible to lower wings simultaneously but—in

raising wings—the one with the least load will come up first.

The gear-type flow equalizer, such as you have in figure 42, consists of two gear-type motors, both of them using a common drive shaft.

Fluid from the selector valve enters the inlet

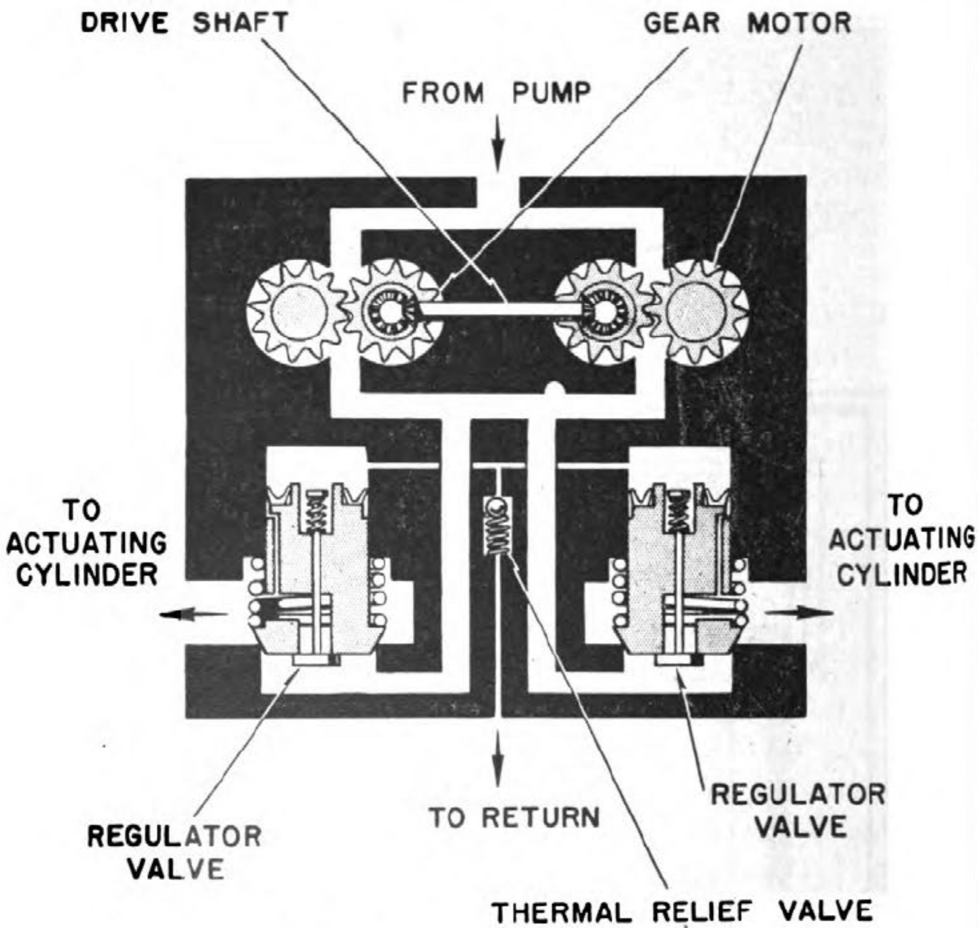


Figure 42.—Gear-type flow equalizer.

port of the flow equalizer, and from there it flows to both motors. As these motors have to revolve at the same speed, the flow is divided equally to the two working lines. The regulating valves at the working line ports are installed to maintain the same back pressure on both motors. This installation is to insure an equal amount of internal leakage past both sets of gears. The

thermal relief valve in the housing is there to compensate for thermal expansion in the working lines.

SEQUENCE VALVES

The sequence valves are the parts of the aircraft hydraulic system that make sure no one "puts the cart in front of the horse." A sequence valve sees that things happen in their proper sequence and that's where it gets its name. For example, when the landing-gear wheel well is closed

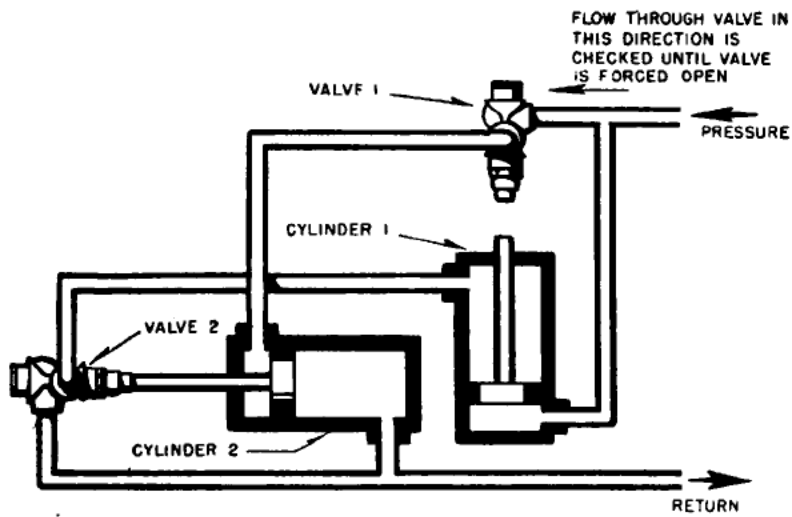


Figure 43.—Sequence valves.

by doors, it is essential that the doors open before the gear is lowered. A sequence valve sees that they do.

If the doors are operated by actuating cylinders which are independent of the gear-retracting cylinders, a sequence valve is installed so that fluid pressure will not be directed to the gear cylinder until the doors are opened.

Usually, another sequence valve is installed in the circuit so that the door closing cylinder cannot be actuated until the landing gear is retracted. A typical circuit using sequence valves in this manner is shown in figure 43.

A sequence valve is merely a ball-type or poppet-type check valve with a plunger for lifting the valve from its seat. Figure 44 shows a ball-type sequence valve.

In operation, the sequence valve is connected in the system so that fluid flow in one direction is permitted at all times. Fluid flow is prevented in the other direction until the plunger is depressed, lifting the ball from its seat.

The sequence valve is installed in a position where the first unit to be operated strikes the

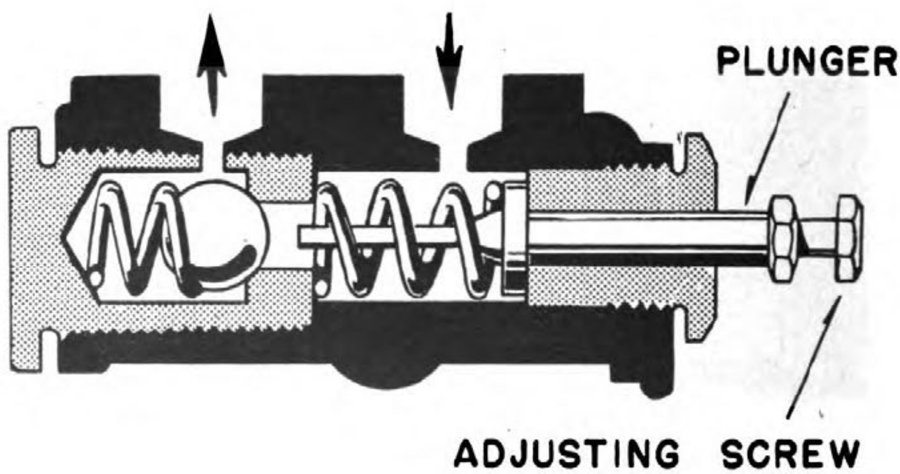


Figure 44.—Ball-type sequence valve.

plunger at the end of its travel. Fluid is then free to flow to the remaining unit.

Spend some time familiarizing yourself with the symbols and legends displayed in figure 45. Your knowledge of them will help you to understand the Technical Notes and Orders of the Bureau of Aeronautics and manufacturers' bulletins and manuals. You'll also run across them in hydraulic system diagrams in this book.

If you know the hook-up of any one system and the purposes of each unit involved, you should be able to tackle any system that comes along.

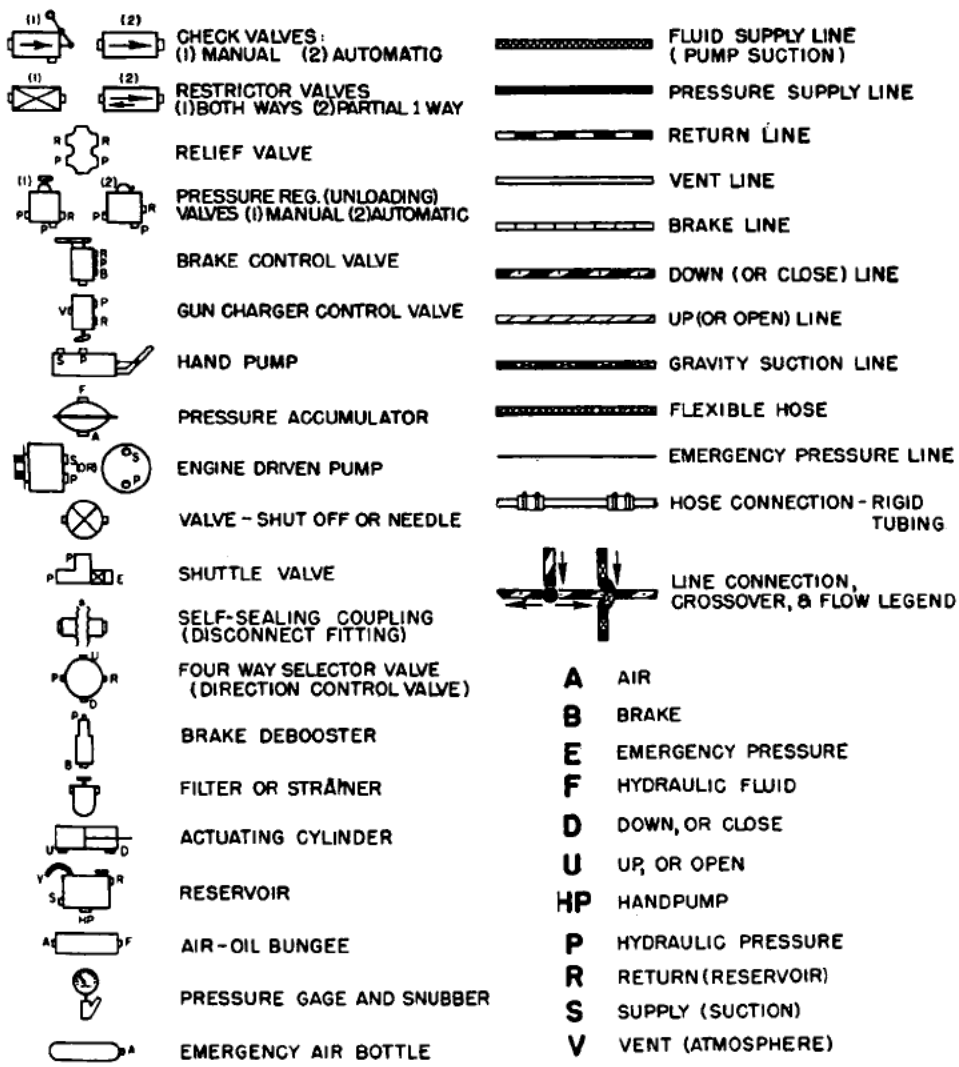
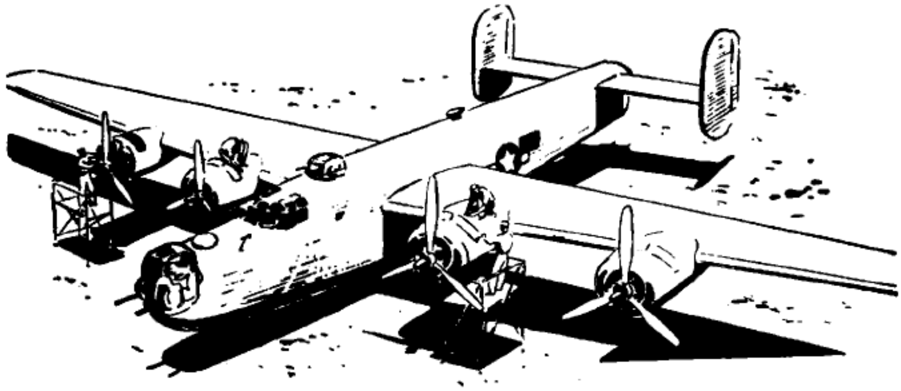


Figure 45—Hydraulic symbols and legends.



CHAPTER 5

BRAKES AND STRUTS

HYDRAULIC BRAKES

Wheel brakes on airplanes are used only when the aircraft is not an AIRcraft—when it's on the ground or flight deck. They're a mighty important piece of equipment though, and are used to turn the airplane when taxiing and to stop its forward motion after landing. Unlike automobile brakes, aircraft hydraulic brakes have a separate control for each brake.

Power for brake operation is provided either from the airplane's main hydraulic system or by a master cylinder for each brake.

There are three distinct types of hydraulic brakes used on aircraft.

The INTERNAL-EXPANDING SHOE BRAKE is similar to those on automobiles and trucks and is used chiefly on single-engine airplanes.

EXPANDER-TUBE BRAKES are used on both single-engine and twin-engine aircraft. They are adaptable particularly for use on amphibian aircraft and on seaplane beaching gear, because they have few moving parts and are not affected by water to any extent.

MULTIPLE-DISK BRAKES are used generally on multi-engined aircraft and on large single-engine airplanes. This type provides a greater braking surface than the other two.

INTERNAL-EXPANDING SHOE BRAKES are composed of a circular brake shoe of fiber or other suitable material mounted on a metal frame. When the brake pedal is depressed this shoe is expanded against the inner surface of a circular metal brake drum, which is an integral part of the wheel assembly. The brake shoe may be all one piece or it may consist of two separate parts joined by a suitable linkage.

Only the two-piece shoe brake is described here but the principle of the single-shoe brake is the same.

Internal-expanding shoe brakes are divided into two classifications, SINGLE-SERVO and DUO-SERVO brakes. The term "servo" refers to the use of the rotary motion of the wheel to further expand and apply the brake.

In SINGLE-SERVO brakes, the servo action is effective for one direction of wheel rotation only and, therefore, the brakes are not interchangeable between the right and left wheels of an airplane. The brakes are marked with the direction of rotation of the wheels with which they are designed to be used. The marking indicates the direction of rotation as viewed from the WHEEL side of the brake.

DUO-SERVO brakes are effective for either direction of wheel rotation. They are interchangeable between the left and right wheels of an airplane, and are effective for both forward and backward motion of the aircraft.

Single-servo brakes have only one piston in the actuating cylinder. This piston acts to expand one end of the brake shoe against the wheel drum.

The brake actuating cylinder on duo-servo

brakes has two pistons. Both ends of the brake shoes are expanded against the brake drum simultaneously.

The construction of a single-servo brake assembly is shown in figure 46. This brake is designed for counterclockwise wheel rotation.

The single-servo brake illustrated consists of a bracket, called the TORQUE ARM, which is used to secure the assembly to the landing-gear brake

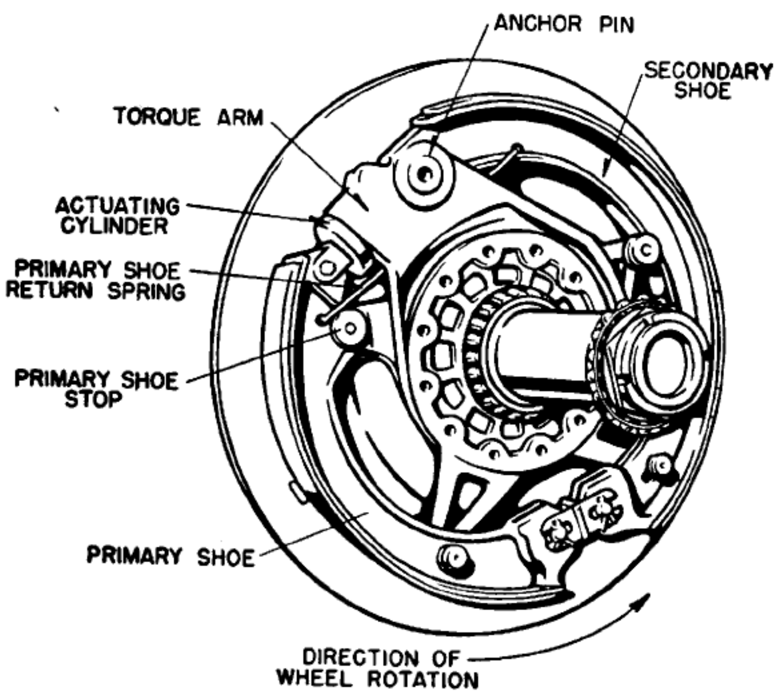


Figure 46—Single-servo brake assembly.

flange, a two-piece shoe, and an actuating cylinder.

The shoe is hinged on one end of the torque arm and, on the other end, to the piston rod of the actuating cylinder. The actuating cylinder is an integral part of the torque arm.

The part of the shoe attached to the piston rod is called the PRIMARY SHOE, and the other part is the secondary shoe. The application of fluid pressure to the actuating cylinder causes the primary shoe to expand against the wheel drum as the piston is extended in the cylinder. Rota-

tion of the wheel drum in the direction indicated by the curved arrow then causes the shoe to expand further and applies the secondary shoe, increasing the braking pressure.

When fluid pressure in the actuating cylinder is released, a coil spring connected between the two shoes draws them together and thus releases the brakes. This action forces fluid from the actuating cylinder back into the brake master cylinder or power-brake debooster valve.

The duo-servo brake, as illustrated in figure 47, is similar to the single-servo except that instead of one end of the brake-shoe assembly being anchored to the torque arm by a stationary pin, it is connected to a second piston in the actuating cylinder. When hydraulic pressure is admitted to the actuating cylinder, the application of force is transmitted in opposite directions, through connection links, to the two ends of the shoe assembly.

These duo-servo brakes are either single or two-shoe construction and can be used as either right-hand or left-hand brakes simply by reversing the return springs.

The EXPANDER-TUBE BRAKE consists of three main parts—the brake frame, expander tube, and brake blocks.

Two types of expander-tube brakes are in use. The SINGLE style has one row of brake blocks around the circumference while the DUPLEX style has two rows of blocks.

An inner shield fits between the flange on the axle and the brake frame to protect the frame from water. The brake expander tube is a hollow tube of rubber compound and fabric and is stretched over the brake frame between the side flanges.

The brake blocks are made of special material and the number used corresponds to the number

of inches of brake diameter. A 20-inch brake would have 20 blocks. These blocks have notches on their sides to engage with bosses on the brake frame so that they will not rotate around the frame. Flat springs fit into slots in both the blocks and frame and hold the blocks against the expander tube and prevent them from dragging when the brake is released.

The expander-tube brake is operated by fluid

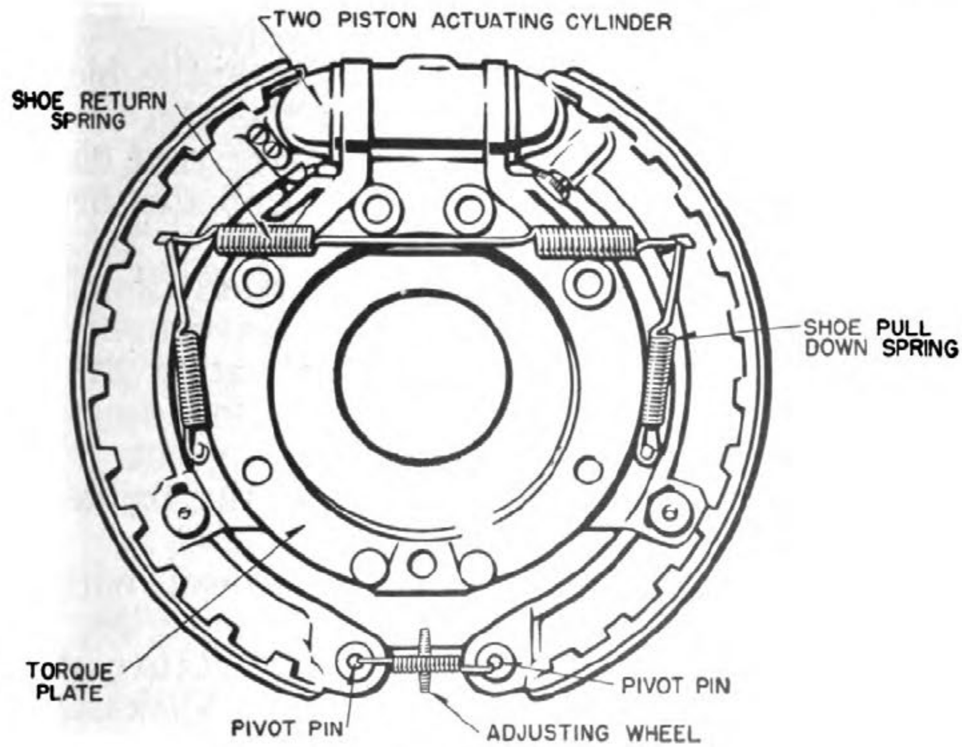


Figure 47.—Duo-servo brake assembly.

pressure and may be used with any of the conventional hydraulic brake systems. When the pilot applies the brake pedal, the pressure sends fluid into the expander tube. This tube is restrained from moving inward or to the sides. The fluid in the tube therefore forces it to expand outward and thus to apply the brake blocks against the brake drum.

As soon as pressure within the expander tube

is released, the springs in the ends of the blocks force the blocks against the expander tube and eject the fluid from the tube. This action is assisted by the tube itself which is slightly smaller than the brake frame. The tube also tends to retract itself without the aid of the springs in the blocks.

EACH BLOCK IS INDEPENDENT IN ITS ACTION. THERE IS NO BUILD UP OF SERVO ACTION AND THEREFORE NO TENDENCY OF THE BRAKES TO "GRAB."

The radial clearance between the brake blocks and the brake drum varies with the size of the brake. There is no way of changing this clearance except by grinding the face of the brake blocks.

As the brakes wear in service, fluid displacement of the brakes increases. This causes the pedal movement required for application of the brake to be increased a corresponding amount. When the pedal travel becomes too great, it is necessary to install new blocks in the brake to reduce the clearance.

A cross-section of an airplane wheel with a MULTIPLE-DISK brake is shown in figure 48. In this brake, resistance to rotary motion is furnished by a series of rotating and stationary disks.

One set of disks, called the STATIONARY PLATES, is keyed to the brake anchor bracket. These disks are free to slide endwise on the bracket but cannot rotate with the wheel. The rotating disks are known as ROTOR plates.

The two sets of plates are assembled alternately. The plate assembly is held on the anchor bracket by an annular, or ring-shaped, retaining nut and a lock spring.

With the brake in the released position, a clearance is maintained between the plates. This clearance is adjusted by the plate retaining nut.

An ANNULAR GROOVE running completely around the circumference of the anchor bracket serves as an actuating cylinder.

A synthetic rubber seal and metal piston, both cup-shaped, are placed in the annular groove in such a manner that the piston bears on the inboard stationary—or stator—plate. The introduction of fluid under pressure into the annular groove forces the piston seal against the piston

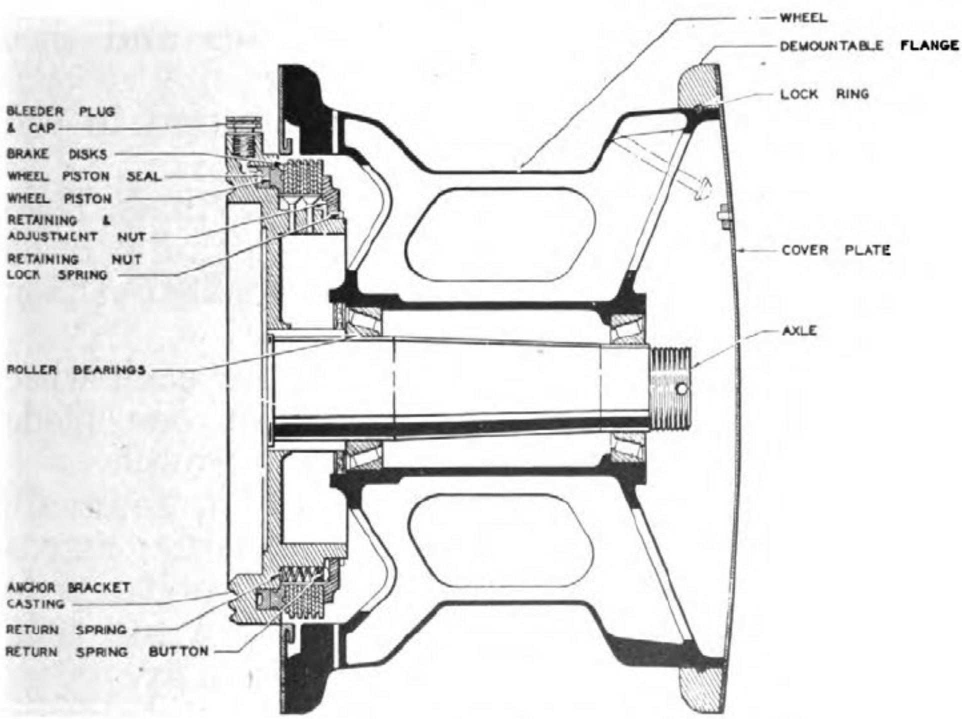


Figure 48.—Cross-section of a multi-disk brake.

and tends to move the piston out of the groove.

Since the piston bears against the inboard stator plate and because the plate is free to slide endwise, fluid pressure causes the plates to be compressed between the piston and the locknut. Wheel rotation is resisted by the friction set up between the surfaces of the rotor plates and stator plates.

Upon release of the fluid pressure, the piston is forced back into the annular cylinder by a

return spring. Pressure on the plates is then released and the wheel can rotate freely again.

The amount of braking surface, and thus the amount of braking action for any one pressure, can be varied by altering the number of plates. The amount of braking surface can also be changed by increasing or decreasing the diameter of the plates. Thus, on large heavy aircraft, the brakes would normally consist of a large number of large diameter plates. On a smaller airplane, both the number of plates and their size would be smaller.

Now take a look at the controls used in conjunction with the brakes.

First, meet the BRAKE MASTER CYLINDERS. These are the energizing units of the hydraulic brake system when the brake control is separated from the main hydraulic system.

One master cylinder is supplied for each wheel brake. A cross section drawing of one model of a master cylinder is shown in figure 49.

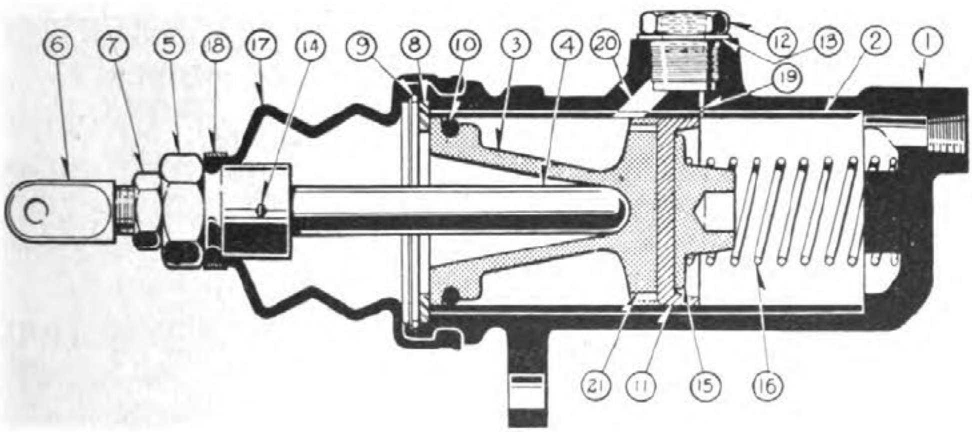
A master cylinder is essentially a manually operated, single-acting RECIPROCATING PISTON PUMP. It is usually mounted on the rubber pedal of the airplane and is controlled by a toe pedal which is part of the rudder pedal assembly.

Most master cylinders have their own reservoirs for housing the fluid used in the brake system. In some models, however, fluid is supplied to the master cylinders from a common fluid reservoir. In either case, the reservoir is vented and fluid is fed to the working chamber by gravity.

When the pilot applies pressure to the toe pedal of the master cylinder, shown in figure 49, the piston is advanced in the cylinder and compresses the coil spring. This causes the fluid in the master cylinder to be forced into the line leading to the brake actuating cylinder and the brake is applied.

When the pilot releases pressure on the toe pedal, springs in the brake assembly cause the fluid in the actuating cylinder to be FORCED BACK THROUGH THE TUBING TO THE MASTER CYLINDER. This, together with the action of the coil spring in the master cylinder, returns the master cylinder piston to the RELEASED position.

A compensating port is installed to prevent the brakes being applied by fluid expansion from temperature increases. It also serves the pur-



1-CYLINDER
2-SLEEVE
3-PISTON
4-PISTON ROD
5-COUPLING
6-CLEVIS
7-HEX CHECK NUT
8-PISTON STOP
9-LOCK WIRE
10-PISTON SEAL (SECONDARY)
11-PISTON CUP
12-CONNECTOR
13-GASKET
14-COTTER PIN
15-SPRING SEAT
16-COIL SPRING
17-BOOT
18-BOOT STRAP (SMALL)
19-COMPENSATING PORT
20-GRAVITY INLET PORT
21-PISTON HEAD PORTS

Figure 49.—Cross-sectional view of a master cylinder.

pose of insuring that the operating chamber is completely filled with fluid at all times.

This compensating port provides a passage between the fluid reservoir in the master cylinder and the operating chamber whenever the brake pedal is released. The fluid is thus permitted to flow from the operating chamber to the fluid reservoir if the fluid is expanded by heat, or from the reservoir to the operating chamber to replenish fluid lost by leakage or contraction.

When the brake pedal is applied, the first few degrees of movement cause the piston to move

forward in the cylinder, closing the compensating port and sealing the operating chamber.

Some brake systems are fitted with a PARKING BRAKE so that the brakes can be locked in the applied or ON position. The parking brake is a manually controlled latch used to lock the toe pedal in the depressed position.

POWER-BRAKE CONTROL VALVES are used to control the flow of fluid to and from the brake mechanism and thus control the operation of the brakes.

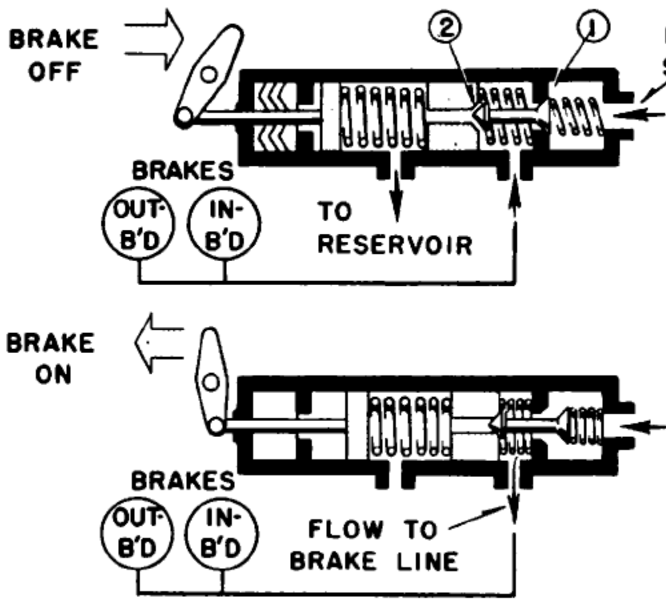


Figure 50.—Power-brake control valve.

There is a power-brake control valve for each brake. The two valves may be combined in one housing or may be separate units. They are operated by toe pedals.

There are several models and types of power-brake control valves. The type shown here is similar to the one used most often on Naval aircraft.

In the valve shown in figure 50, fluid under pressure from the aircraft hydraulic system enters the valve through the POWER SUPPLY PORT. With

the pressure poppet valve *1* held in the position shown by its spring, fluid cannot flow beyond this point. The return poppet valve *2* is attached to the pressure poppet so that its motion is related directly to that of the pressure poppet. With the pressure poppet on its seat, the return poppet cannot move farther to the left.

The return poppet seat is in a movable piston which, with the control valve in the OFF position, is held by the action of its spring in the position shown—or so that there is some clearance between the valve and its seat.

When the piston is in this position, fluid is free to flow from the line leading to the brake, through a passage in the piston, and to the reservoir by way of the return port. THIS CONDITION EXISTS WHEN THE BRAKES ARE RELEASED.

When the brake pedal is depressed, the piston is pushed toward the return poppet and the poppet is seated in the piston. This seals the passage from the brake line to the return port.

As the brake pedal is depressed further, the pressure poppet is lifted from its seat and fluid under pressure is free to flow from the power-supply system to the brake. As the pressure in the brake line becomes greater, fluid pressure on the sliding piston is increased until it reaches a point where it overcomes the pressure of the spring between the piston and the actuating rod. This moves the piston to the position where the pressure poppet is closed.

Varying the pressure applied to the brake pedal causes the tension of the spring to be varied accordingly. Consequently, the fluid pressure required to move the piston to the position where the pressure poppet is closed, also varies. Increasing pedal pressure increases the pressure applied to the brakes and a reduction in pedal pressure reduces the pressure applied to the brakes.

POWER-BRAKE DEBOOSTERS are used to reduce the system pressure necessary for brake operation. They also provide a means of quickly releasing the pressure on the brake actuating cylinder when the pressure from the control valve is released.

The debooster is a steel barrel fitted with a spring-loaded piston that divides the cylinder into two chambers. The high-pressure, small-volume chamber is connected to the brake-control valve. The low-pressure, large-volume chamber is connected to the wheel-brake actuating cylinder. See figure 51.

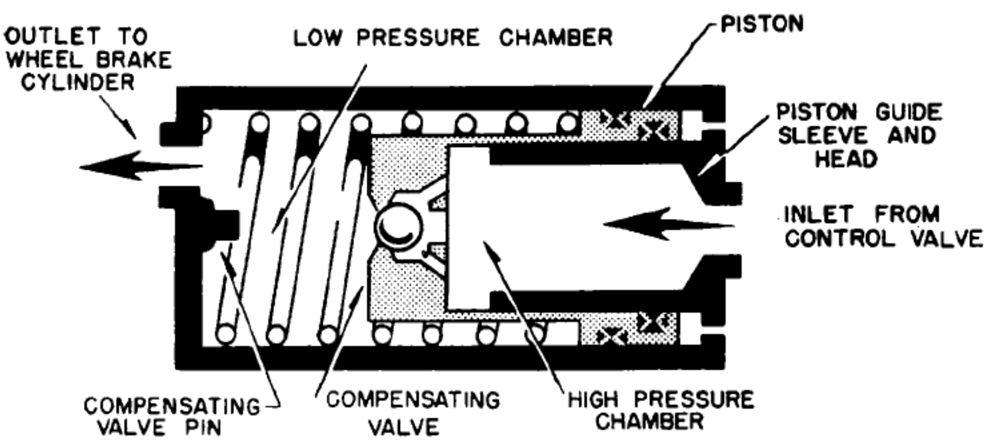


Figure 51.—This is a power-brake debooster.

The piston contains a ball-type compensating valve and suitable packing. The end fitting at the inlet end provides a piston guide and has an integral boss for a threaded connection.

The debooster is inserted in the wheel-brake system between the brake control valve and the actuating cylinder so that the piston in the debooster divides the wheel-brake system into two separate fluid channels. One channel is connected to the brake control valve and the other to the brake actuating cylinder.

Fluid pressure from the control valve acts on the inside of the piston to move it against the

pressure of the return spring. This motion FORCES FLUID from the low-pressure chamber into the BRAKE ACTUATING CYLINDER. Consequently, the force applied to the brake shoe depends on the pressure applied from the brake control valve.

When this pressure is diminished or released, the piston return spring drives the piston away from the outlet end and thereby unloads a corresponding amount of fluid from the actuating cylinder. THE BRAKES ARE THUS RELEASED.

When the wheel brake is applied fully, the pistol in the debooster moves nearly the full length of the cylinder to displace a volume equal to the total volume of the operating cylinder or expander tube. It does not travel quite far enough, however, to cause the pin in the outlet end of the cylinder to open the compensating valve. This is because the total volume of the low-pressure chamber is 2 or 3 cubic inches greater than the maximum wheel-brake requirement to provide for minor fluid leakage.

When fluid leakage exceeds this amount, the piston will move close enough to the outlet end of the cylinder to cause the pin to open the compensating valve. Then, fluid moves from the high-pressure chamber to the low-pressure chamber.

Fluid continues to flow into the low-pressure chamber until the fluid volume in this chamber increases sufficiently to move the piston away from the pin and close the valve. Because of the pressure area differential between the two chambers, the pressure applied to the wheel brake when the compensating valve is open cannot exceed the maximum low pressure normally developed by the piston during its strokes.

SHOCK ABSORBER

The shock-absorber strut on an airplane acts much like a Pogo Stick. The chief difference

between the two is that the Pogo Stick works by spring action and the shock-absorber strut works by hydraulic action.

Aircraft shock-absorber struts absorb and dissipate the shock of landing, and also perform the duties of an automobile shock absorber by allowing smooth riding of the airplane while it is taxiing.

In some installations, the strut takes compression loads only. In others, it also takes bending and torsion loads. In the latter case, the strut is equipped with a sliding spline or scissors arrangement to prevent the piston from turning in its cylinder.

Almost all modern aircraft use the "OLEO PNEUMATIC" type struts in which the use of oil and compressed air are combined to eliminate shock. The oil is stored in a lower chamber connected by a small passageway to the upper air chamber. A metering pin affixed to the top of the piston enters this passageway to control the flow of oil into the air chamber as the strut absorbs shock.

The air in the upper chamber acts as a cushion or spring to absorb the shock.

The strut illustrated in figure 52 uses the scissors arrangement to prevent rotation of the two parts as described. At the bottom you will see the stub axle to which the wheel and brake assembly is fitted. Points as shown are used to attach the strut to the airplane and to brace it.

Torsion links or scissors form a flexible connection between the strut cylinder and piston tube. Air is put in the compressed-air chamber according to the amount necessary to obtain CORRECT EXTENSION OF THE PISTON WITH RELATION TO ITS CYLINDER.

The oil chamber is filled with fluid when the piston is at the bottom of its stroke in the cylinder.

The piston tube is highly polished and is chrome

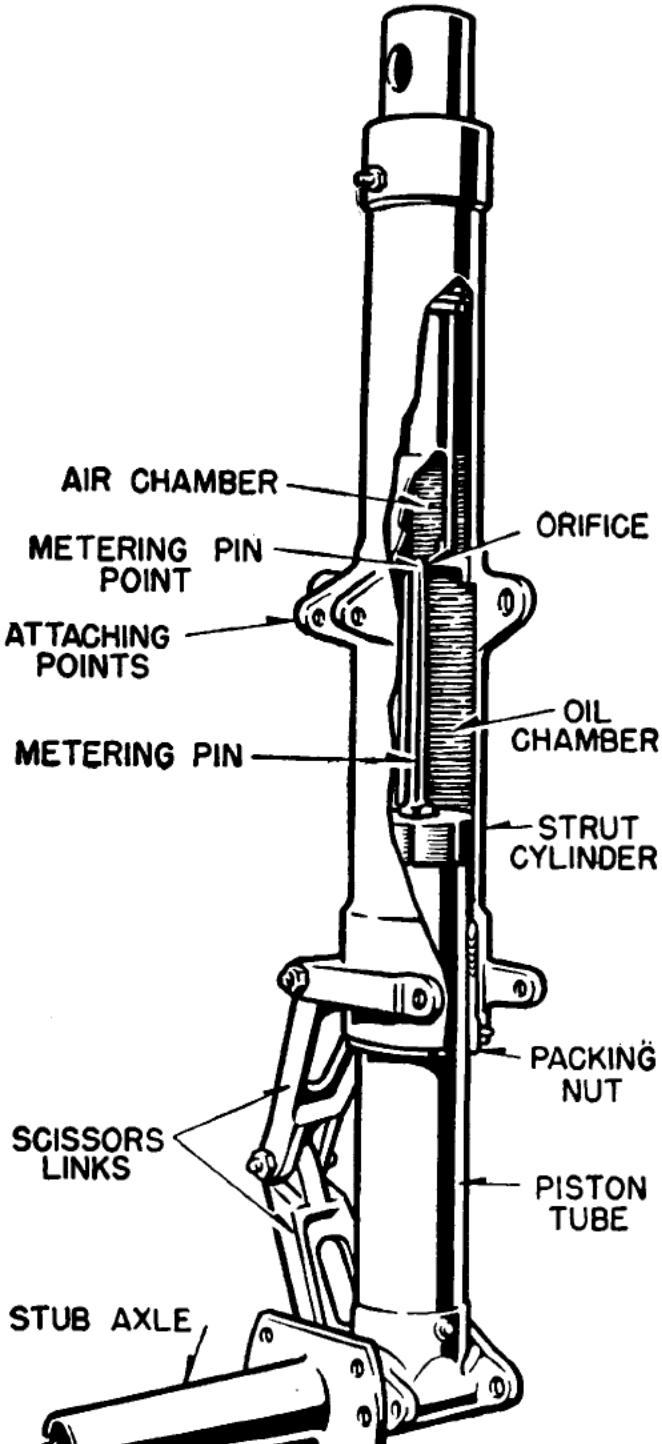


Figure 52—Oleo-pneumatic shock-absorbing strut.

plated. Leakage of fluid between the piston and cylinder is prevented by special packing held in compression by a packing retaining nut screwed into the strut cylinder. The point of the metering pin governs the amount of energy dissipated when the strut is compressed under the load of landing.

HERE'S HOW THESE PARTS TEAM UP IN ACTUAL USE.

When an airplane makes a landing, the wheel hits the ground and the upward thrust telescopes the piston into the cylinder.

As the piston rises, the oil in the fluid chamber is forced through the orifice between the oil and air chambers around the metering pin. The orifice controls the flow of the fluid and thereby creates a hydraulic resistance to slow up the speed at which the piston moves upward.

The flow of fluid from the oil chamber into the air chamber compresses the air and INCREASES the resistance to the upward movement of the piston.

Small shocks encountered when taxiing the plane are absorbed in a similar manner but, of course, are on a smaller scale. The fact that the air in the upper chamber is compressible causes it to act like a spring in absorbing the minor shocks, and the plane thus rides smoothly.

SHIMMY DAMPER

The shimmy damper is installed on the nose wheel of all military airplanes equipped with tricycle landing gear. Without the shimmy damper the nose wheel would oscillate violently.

Figure 53 shows a schematic diagram of the operation of a shimmy damper.

The pre-load pressure of the accumulator acting on the pistons holds the wheel in neutral position. When the wheel oscillates to the left, the left piston resists the turning motion. In order that the piston

might move, oil must be displaced through the small hole in the orifice check valve. When the wheel is returning to neutral, the orifice check valve opens, permitting a free flow of liquid

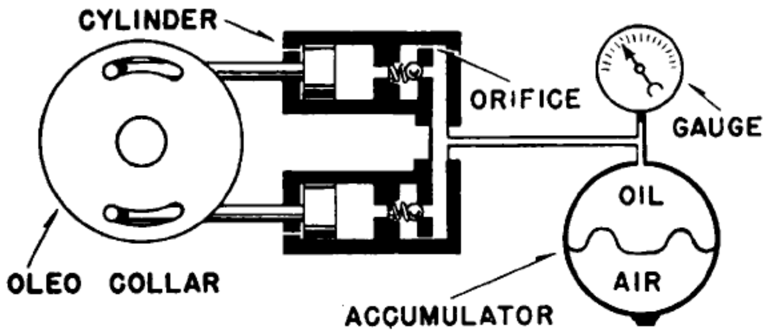
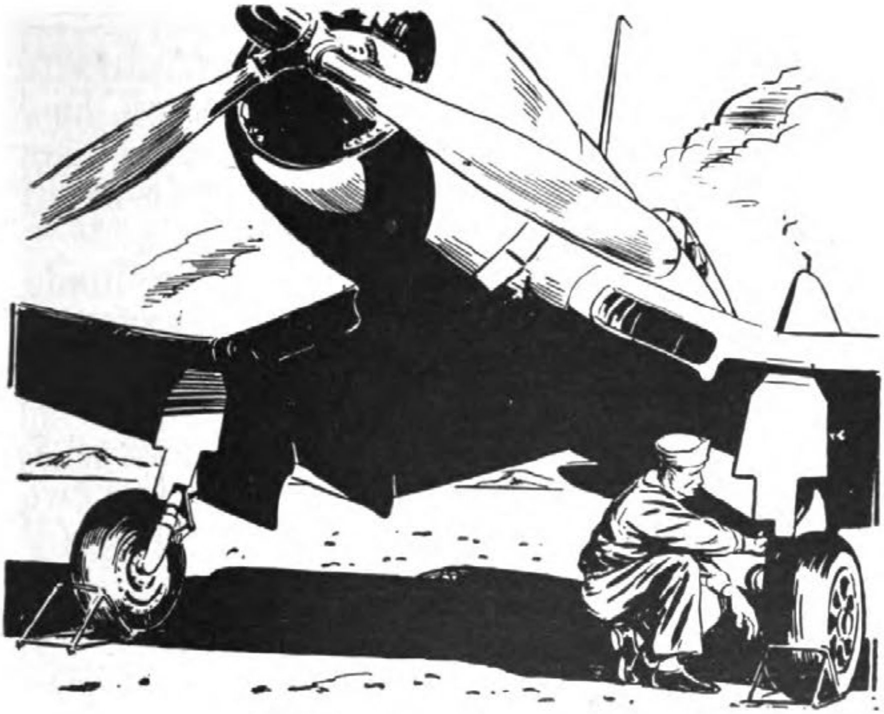


Figure 53.—Shimmy damper.

under pressure. This assures a fast return action of the wheel.

Oscillations of the wheel to the right are damped in the same manner by the cylinder on the right side of the oleo collar.



CHAPTER 6

HYDRAULIC TURRETS

KNOW THE CODE

You'll run across quite a few different makes of turrets on Navy airplanes. They are identified readily if you know how to read the manufacturers' name plates.

FOR EXAMPLE—

Take the Martin 250 SH–2 bow turret which is installed on a PB2Y–3.

First, the name "Martin" means that the turret is manufactured by the Glenn L. Martin Company. The number "250" means that the turret is armed with two .50 caliber machine guns. The first letter in the code "SH" tells you that the turret is SPHERICAL in shape. The "H" informs you that it is hydraulically operated. The number "2" at the end is merely a modification number.

SOME OTHER EXAMPLES—

"CONSAIR 250 CH–4." Turret is manufactured by the Consolidated Aircraft Corporation, has two .50 caliber guns, is cylindrical in shape, and is operated by hydraulics. It is the fourth modification of the model.

"GRUMMAN 150 SE–1." Turret is made by Grumman Aircraft Corporation, is armed with one .50 caliber gun, is spherical in shape and is operated by ELECTRICITY.

"ERCO 250 TH–2." Turret is a product of Engineering and Research Corporation. It has two .50 caliber guns, is SHAPED LIKE A TEAR DROP (T for tear) and is operated by hydraulics.

Here's a representative list of turrets and the airplanes on which they are installed.

TURRET	AIRPLANE
Martin 250 SH–2.	Bow of PB2Y–3.
Martin 250 CH–3.	Upper waist of PB2Y–3.
Consair 250 CH–4.	Tail of PB2Y–3.
Grumman 150 SE–1, 2.	TBM and TBF
ERCO 250 TH–1.	Right waist turret, PB4Y–2.
ERCO 250 TH–2.	Left waist turret, PB4Y–2.
Emerson 250 CH–2.	Bow, some PB4Y–2.
Emerson 250 CH–4.	Forward upper waist, some PB4Y–2.
Emerson 250 CH–5.	After upper waist, some PB4Y–2.
Emerson 250 CH–6.	Tail, some PB4Y–2.
Vought 150 CH–1.	TBY.
Martin 250 SH–3.	Bow of the PBM.
Martin 250 CH–1.	PBM, upper deck.
Martin 250 CE–16	Forward upper waist, some PB4Y–2.
Martin 250 CE–17.	After upper waist, some PB4Y–2.
Motor Prod. Corp. 250 CH–5.	Tail of some PB4Y–2.
Motor Prod. Corp. 250 CH–6.	Nose of some PB4Y–2.

TURRET—Continued	AIRPLANE—Continued
Martin 250 CH–2.	Tail of PBM.
Emerson 250 CH–3.	On several.
Curtis 150 CH–2.	SB2C, SBW and SBF.
Norge 150 CH–2.	SB2C, SBW and SBF.
ERCO 250 SH–2.	Bow of some PB4Y–1.

GETTING SPECIFIC

This listing makes turrets appear to be highly complicated mechanisms of many different designs. They can all be broken down, however, into two mechanical and two hydraulic classifications.

Mechanically, turrets are classified according to their shape. First, there is the ball, or spherical, type in which the guns are fixed to the turret and the gunner moves with the guns in both AZIMUTH (horizontal) and elevation training of the guns. The second type is the cylindrical turret in which the gunner (and turret) move in azimuth only and the guns pivot in elevation.

Hydraulically, turrets are classified into those having valve control and those that are controlled by a pump.

VALVE CONTROL

If the turret's speed and direction are controlled by a valve connected to the control handles—the valve-control type—its basic flow diagram is similar to that sketched in figure 54.

From this basic diagram, the flow diagram of any valve-controlled turret can be constructed by making additions as dictated by the hydraulic, mechanical, and structural requirements of the turret itself.

The source of power in the system diagrammed in figure 54 may be a Vickers Variable Displacement Pump or it may be a hydraulic swivel in the

base of the turret, which gets its supply of hydraulic power from an outside panel or from the

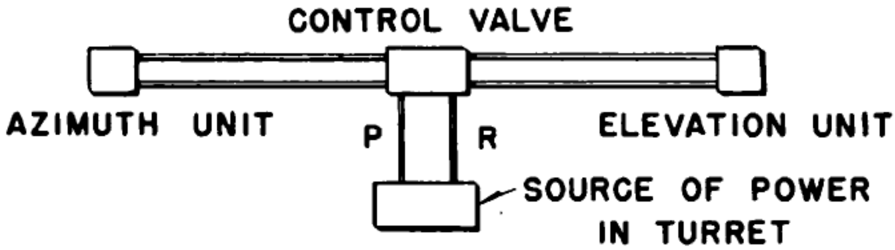


Figure 54.—Basic diagram, valve-controlled turret.

airplane's main system. Any suitable control valve (Clarke, Vickers, etc.) can be used in this system.

PUMP CONTROL

Turrets controlled by pumps are operated by varying the direction and rate of flow of the pump. This method of control necessitates the installation of separate pumps for elevation and azimuth movement of the guns. The most common turrets of this type are the Sperry and Emerson makes, which use the Vickers Double-Power Unit.

250 SH–2 MARTIN BOW TURRET

The Martin 250 SH–2 turret is mounted in the bow of the Navy's PBM, PB2Y and PB4Y airplanes. It has a self-contained hydraulic system, carries 800 rounds of ammunition, has a fixed illuminated sight and is designed to operate satisfactorily under all combat conditions.

Hydraulic power in this turret is furnished by a VICKERS VARIABLE-DISPLACEMENT PUMP, which is a complete hydraulic actuating system. It contains a reservoir, pump, compensating valve (which acts as a regulator), emergency or system relief valve, and a supercharger to pressurize the reservoir. The pressure output of this pump can be regulated by turning a set screw on the compensating valve. This is the only external adjustment on the pump unit.

If the system relief valve—located on the valve plate of the pump—needs adjusting, the pump must be removed from the turret. The adjustment can then be made by removing the cover plate and diaphragm retainer and turning the adjusting screw in the valve plate of the pump.

When adding air to the supercharger after filling and bleeding the system, pump only as long as the reservoir pressure gage continues to rise or until the pressure reaches 30 pounds. If the

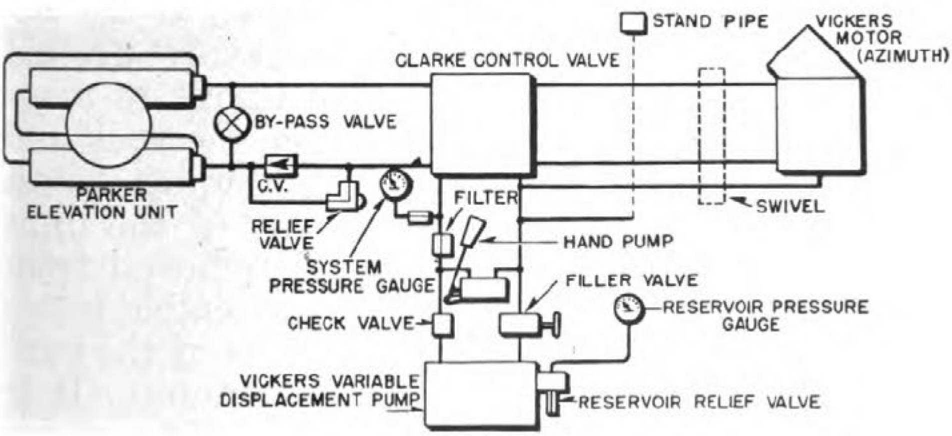


Figure 55.—Flow diagram of the Martin 250 SH–2 hydraulic system.

gage needle fails to register or stops rising before the desired pressure is reached, the reservoir is low on fluid and must be refilled.

A CLARKE CONTROL VALVE controls the direction and speed of the turret and contains the control handles, safety or "dead man" switches and trigger switches. This valve must be removed from the turret and placed on the test stand for proper adjustment.

To adjust this valve, loosen the locknuts and turn out all cages (shown in figure 56) two full turns. Connect the pressure port. Test pressure is approximately 1,000 psi. Hold the control handles in the center position in both azimuth and elevation. Now turn the cages in until they begin to leak and then back them off until the leaking

stops. If the valve handles are held in the central position, the valve should be adjusted properly with a minimum of neutral play.

If the valve still does not function properly, consult the manual for further directions.

The MOTOR which turns the turret in AZIMUTH is a Vickers seven-piston motor located at the azimuth ring of the turret.

The Parker ELEVATION UNIT consists of two balanced actuating cylinders connected to a stationary pinion by a rack gear. It is located at the left trunnion. As the pistons move, they revolve around the stationary pinion causing the turret to move in elevation. Any back lash between the rack and pinion gears can be taken up by tightening the set screws in the top and bottom center of the unit. The Parker elevation unit must be removed from the turret, however, in order to disassemble it.

The HAND PUMP, located to the right of the gunner's seat, is an Adel double-action pump. It is used in the event the power pump fails and for servicing purposes.

A Barco HYDRAULIC SWIVEL is in the left trunnion in the middle of the Parker elevation unit. It contains the three lines to the azimuth motor. The swivel is needed in the system to transmit fluid to the azimuth motor which cannot move in elevation as does the rest of the hydraulic system.

A RELIEF VALVE in this hydraulically-operated turret is installed to prevent the turret from falling forward under its own weight. It is located below the left trunnion. The valve is set at a pressure to balance the weight of the guns, ammunition, armor plate and other equipment. This can be done within the turret by adjusting the valve so that the proper balance is secured or the valve can be set on a test stand at 450 psi. (Do not set it too high.)

ONE CHECK VALVE is located near the hand

pump and prevents hydraulic fluid from going to the power pump when the hand pump is in operation.

A SECOND CHECK VALVE is installed under the elevation unit. Its installation allows the turret to elevate freely but makes it necessary for the

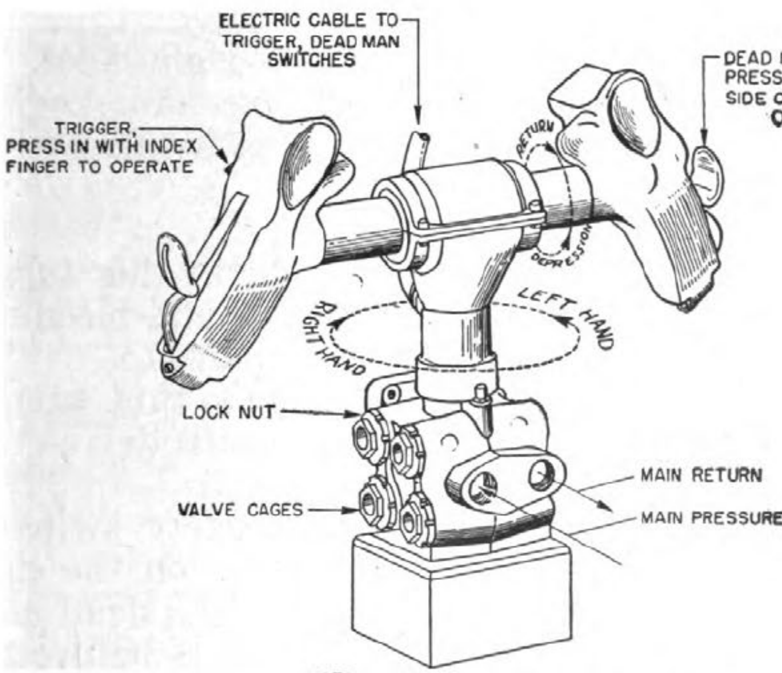


Figure 56.—The Clarke turret control valve.

fluid to pass through the relief valve when the turret is lowered.

Both check valves are the double-ball type to insure the fluid being checked and double-checked.

A BYPASS valve, located at the side of the gunner's left foot, is known as the CASUALTY BYPASS because it can be operated from outside the turret. This allows the turret to return to its stowing position in elevation.

A FILLER VALVE is placed in the turret so that it can be filled and bled in one operation. This

valve must be in the "RUN" position to operate the turret. If it is in the "FILL" position and the pump is operated, the gasket in the housing to the azimuth motor will blow. It should be noted, however, that this gasket WILL NOT BLOW during the filling operation if the valve is connected according to instructions.

The FILTER in this system is a screen-type line filter located above the gunner's right foot. It should be cleaned out at every overhaul period. Be careful not to put this filter in backwards when installing it in the line.

THINGS TO REMEMBER—

Most of the trouble encountered in this turret has been caused by improper filling and bleeding. FOLLOW FILLING INSTRUCTIONS CAREFULLY.

Be careful not to SNAP REVERSE this turret. Rapid reversal may cause the azimuth drive-gear shaft to shear.

Never touch the dead man or safety switches lightly. This will cause the contacts on the electrical relay to weld together. Hold the dead man switch down FOR AT LEAST 3 SECONDS before releasing it. (This is necessary only when the pump motor switch is turned ON.)

250 CH–3 MARTIN DECK TURRET

If you've still got that code in your head, you'll know that this turret has two .50 caliber guns, is cylindrical in shape, and, of course, is operated by hydraulics. It is mounted in the deck position of a PBM, PB2Y or PB4Y airplane.

The hydraulic system in this turret is similar to the one in the Martin bow turret just described and, therefore, only those units which differ from the ones in the 250 SH–2 will be mentioned.

A CONTOUR FOLLOWER VALVE is located in the lower right forward position of the turret and is used to prevent the barrels of the guns from hit-

ting the fuselage of the airplane. It is actuated by a switch following a cam.

The guns in this turret are charged by a BENDIX HYDRAULIC GUN-CHARGER VALVE. This unit is located to the left of the control handles, as shown in figure 57.

AN ACCUMULATOR is installed simply to serve as an auxiliary reservoir. It is charged with a low pressure after filling. (Consult the turret manual.)

The RESTRICTOR FITTING in the line between the

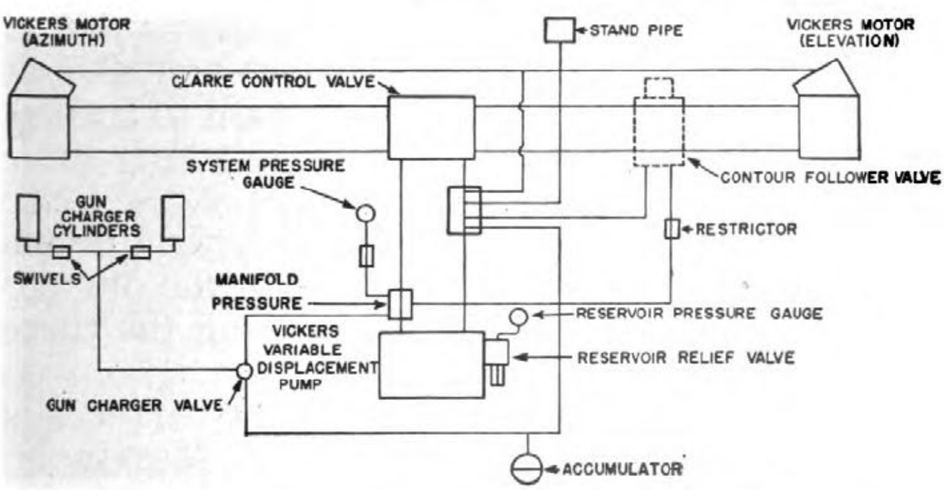


Figure 57.—Hydraulic system in the Martin 250 CH-3 turret.

pressure manifold and the contour follower valve prevents the guns from moving up too rapidly when the contour follower valve is in operation.

250 CH CONSOLIDATED TAIL TURRET

This cylindrical turret is installed in the tail position on the PBM, PB2Y and PB4Y airplanes. It differs from the others chiefly in the fact that it gets its hydraulic power from an actuating panel OUTSIDE THE TURRET. Another unusual feature is that the turret can be operated manually without the use of its hydraulic or electrical systems.

The actuating panel outside the turret contains

a reservoir, gear-type pump, relief valve, check valve, a pressure switch which acts as a regulator, an accumulator and a filter.

The relief valve, pressure switch, and accumulator are adjusted in this manner.

RELIEF VALVE—Should be adjusted to 1,250 psi.

PRESSURE SWITCH—Can be adjusted by turning a setscrew at the bottom of the unit after removing the cap. The switch should be set to cut-out at 1,000 psi and to cut-in at 800 psi.

ACCUMULATOR—Preload pressure is 600 psi.

Inside the turret, the HYDRAULIC SWIVEL is located at the bottom center and is used to transmit fluid from the outside panel to the moving turret.

A SHUT-OFF VALVE is at the right of the control handles. It is used to shut off the hydraulic fluid to the turret. This valve must be in the OFF position when you are entering or leaving the turret, or serious injury may result.

The CLARKE CONTROL VALVE in the turret is adjusted exactly like the one in the Martin bow turret.

The ELEVATION ACTUATING CYLINDER on the left side of the turret is used to elevate both guns. The base of the actuating cylinder contains a hydraulic swivel which permits the cylinder to pivot.

TWO ELEVATION BYPASS VALVES are used during manual operation. The valves are connected by a mechanical linkage and are arranged so that, when they are open, fluid is free to flow from one side of the actuating cylinder to the other and to the return. The valves must be closed for power operation.

STOP VALVES located forward in the bottom of the turret are used to shut off the flow to the azimuth motor when the turret runs up against its azimuth limit stops. The azimuth range of the turret

can be adjusted by turning the set screw in the stop valve. Be certain that you set the limit stops to line up squarely with the set screw on the valve.

An AZIMUTH BYPASS VALVE is located under the seat beneath the gunner's left leg. It is opened when the turret is operated by hand. The handle of the valve has a cable attached to it which is connected to a T-handle outside the turret. This is

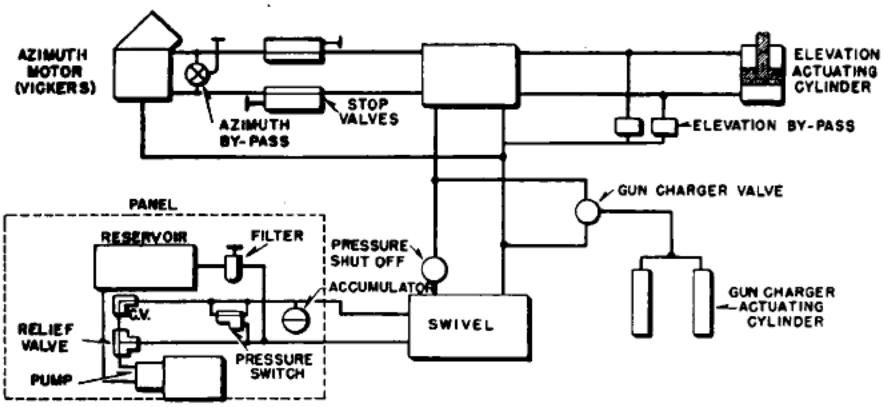
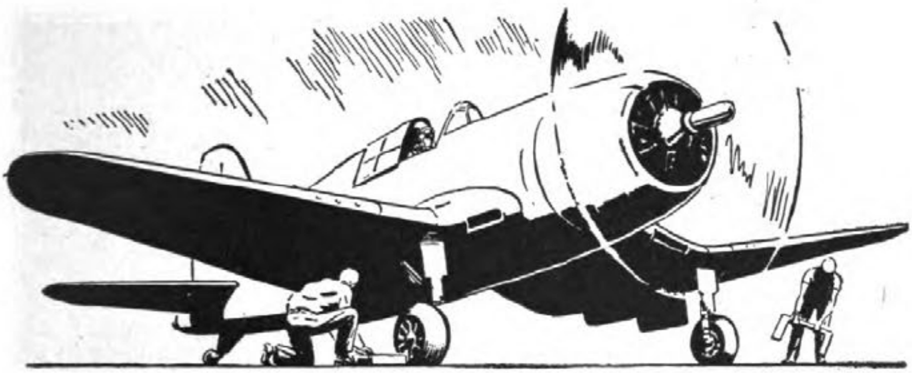


Figure 58.—Hydraulic system for the Consair 250 CH turret.

to turn the turret so that a casualty can be removed.

CAUTION—Always check to make sure that this bypass valve is closed! Sometimes the cable tightens up before the valve is closed. Don't take it for granted that a tight cable means a closed valve.

Generally speaking, this turret hydraulic system has given little trouble and does not require much care as long as the fluid is kept clean.



CHAPTER 7

THE F4U–1 CORSAIR

HYDRAULIC SYSTEM DETAILS

The easiest way to understand a hydraulic system is to trace the flow of fluid from start to finish, pausing as each unit comes into the picture to learn the part it plays in the hydraulics show. This, of course, means starting with the power units which create the flow and regulate the pressure for the system. First unit is the reservoir.

In the F4U, the reservoir is installed at the top of the airplane's engine mount just forward of the firewall. It is secured by metal straps with rubber chafing strips placed between the straps and reservoir. This reservoir contains 2.742 gallons of fluid for operation of the system. Of this amount, 279 cubic inches are above the engine-pump standpipe and accessible to the hand pump for emergency operation.

The reservoir has an air space of 214 cubic inches to allow for fluid expansion. Three lines connect into the reservoir. They are—the supply line to the engine pump, the hand-pump supply line, and the system return line. In addition to these, a small vent line runs overboard. A dip stick in the top of the reservoir allows you to check the fluid level, which must be correct at all times.

The fluid level is measured with the airplane in the three-point position, with the landing gear extended and the flaps up.

When filling the system be sure that the fluid is clean and that you are using AN–VV–O–366A mineral oil as prescribed.

ENGINE PUMP

Following the main supply line from the reservoir—see figure 60—you come to the engine pump. This is a Pesco gear pump mounted on the left-hand side of the engine accessory-drive housing. The pump is the unit in the system which creates flow, and this flow, upon restriction, becomes pressure. The pump displacement is .565 cubic inch per revolution.

The pressure line from the pump goes next to the Purolator filter. Where the pressure line goes through the firewall, there is a line disconnect to allow for quick removal of the pump without loss of fluid. The filter cleans the fluid of particles of dirt that might otherwise stop up the system. The filter can be reached through a plate from outside the plane and must be turned daily to keep it clean.

From the filter, the fluid goes to the Vickers pressure regulator mounted in the cockpit on the center of the forward bulkhead. This regulator acts as a pressure-control valve by automatically diverting the pump output to the reservoir when the system pressure builds up to 1,075–1,150 psi. It also directs the pump output to the accumulator and system when the system pressure drops below 925–1,000 psi.

When the regulator is diverting the flow to the reservoir, it is in the "cut-out" position. When it is directing the flow to the accumulator, it is in the "cut-in" position. Cutting out of the pressure regulator dumps the entire pump output into the return line thus creating a pressure surge. This

Figure 59.—The F4U–1, Corsair in flight.

surge is taken in hand by a surge chamber in the return port of the regulator. A surge chamber, you will remember, consists of two cone-shaped parts separated by a diaphragm.

Smooth operation of the regulator depends a great deal upon the pressure accumulator which is the next unit in line. The accumulator is installed in the cockpit on the left-hand side of the forward bulkhead. It is placed close to the regulator so as to have its best effect on that unit. The accumulator acts as a cushion for the pulsations of the pressure regulator and also supplies an auxiliary supply of fluid when demands on the pump are high.

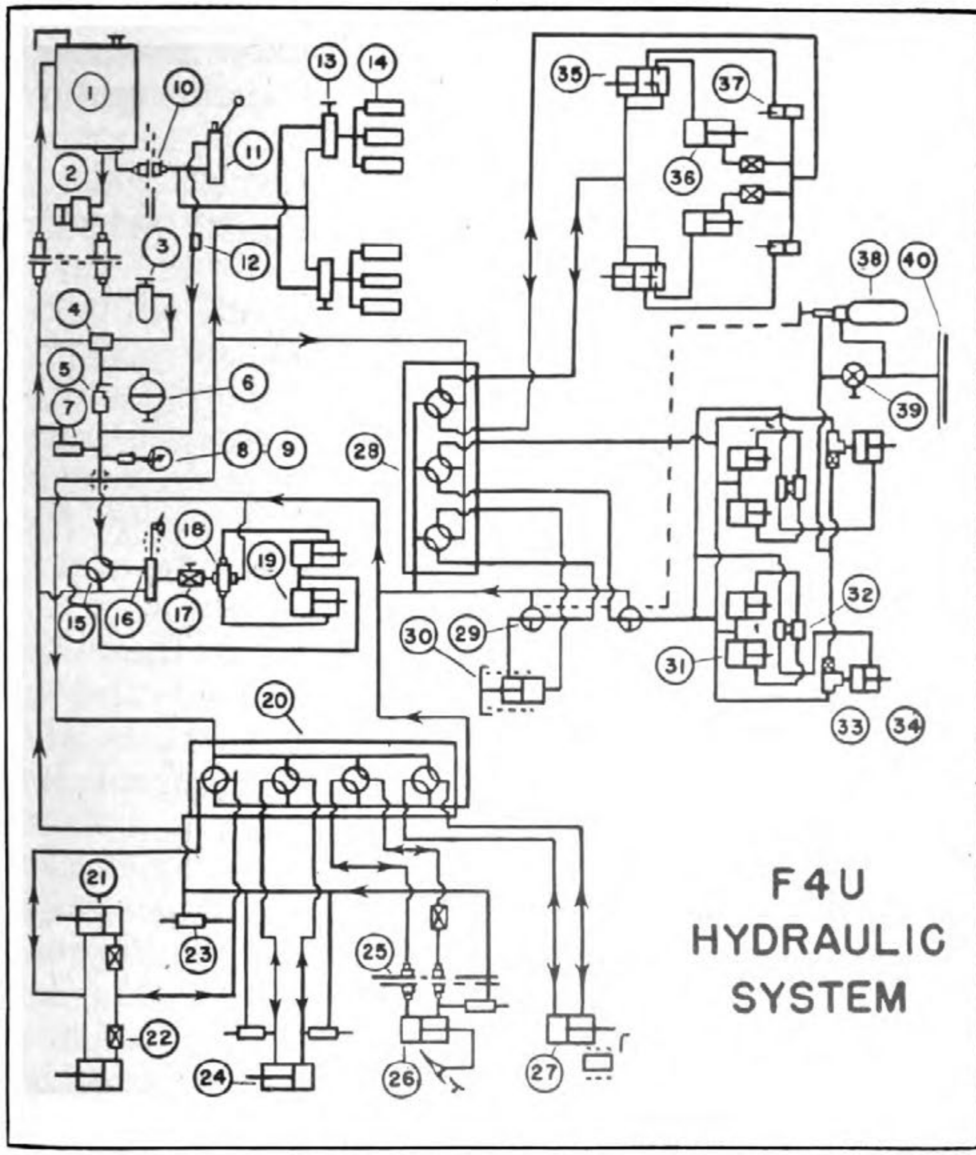
ACCUMULATORS

Two models of accumulators are used in the F4U. One is the Vickers spherical internal-diaphragm. The other is the Simmonds internal-bag type. Both are 5-inch models and both are preloaded to 250 psi while there isn't any hydraulic pressure in the system. When preloaded to this point and with the system pressure built up to 1,000 psi the oil capacity of the accumulator is 49.1 cubic inches.

The pressure line from the hand pump connects into the system just after the accumulator. The hand pump, which is made either by Adel or Air Associates, is the double-acting type, and is mounted on the left-hand side of the cockpit. As you already know, the hand pump draws fluid from the bottom of the reservoir.

There is a line disconnect fitting where the supply line goes through the firewall so that the pump can be removed quickly and without loss of fluid.

A manually-operated check valve is installed between the accumulator and the hand-pump pressure line. This check valve, when turned to "FLIGHT," cuts off the hand pump from the accumulator. Thus, the system can be charged with



1. Reservoir.
2. Engine pump.
3. Filter.
4. Regulator.
5. Manual check valve.
6. Accumulator.
7. Main relief valve.
8. & 9. Snubber & Gage.
10. Quick disconnect.
11. Hand pump.
12. Check valve.
13. Gun-charger valve.
14. Gun-charger struts.
15. Wing-flap selector valve.
16. By-pass valve follow-up.
17. Adjustable restrictor.
18. Flow equalizer.
19. Wing flap struts.
20. Banked selector valve.
21. Oil-cooler strut.
22. Restrictors.
23. Relief valves.
24. Access. Comp't. strut.
25. Fire wall.
26. Cowl-flap strut.
27. Arresting-gear strut.
28. Banked selector valve.
29. Emergency release.
30. Tail-wheel strut.
31. Landing-gear door struts.
32. Sequence valve.
33. Shuttle valve.
34. Landing-gear struts.
35. Pin-pulling strut.
36. Wing-fold strut.
37. Load & fire valve.
38. Bottle.
39. Needle valve.
40. Overboard.

Figure 60.—Diagram of the F4U–1 hydraulic system.

the hand pump if the accumulator should be shot away in combat. When the check valve is turned to "GROUND," the accumulator can be charged by the hand pump.

This check valve is installed on the left side of the cockpit just above the landing-gear selector valve.

The pressure line connects into a manifold block located on the forward bulkhead in the cockpit. This manifold block eliminates the need for excessive tubing and fittings and also acts as a junction box for the hydraulic lines. The main-system relief valve connects into the block. Made by Air Accessories, the relief valve is the ball type and is set to relieve system pressure at 1,250 psi.

The main pressure gage connects into the main pressure line at the pressure manifold and is mounted on the lower right auxiliary panel. The gage is calibrated in 100 psi units and ranges from 0 to 2,000 psi.

These units compose the main power system—supplying and regulating the flow and pressure for the operation of the various units. This pressure must now be directed to the proper end of the actuating cylinders at the correct time for the operation of these units. This job is handled ably by seven Adel poppet-type selector valves and one Fleetwing pre-selector valve.

SELECTOR VALVES

Three of these selector valves are combined in one housing to operate the tail-wheel, landing-gear, and wing-folding operations. Each selector valve, however, is individually operated by a separate cam shaft. A common pressure line and a common return line supply the pressure for the unit. This is called a three-bank selector valve and it is located on the left-hand side of the cockpit.

Four of the Adel selector valves are combined

into a four-bank selector valve operating the oil-cooler shutters, inter-cooler shutters, cowl flaps, and arresting gear. This unit is located on the right side of the cockpit.

The Fleetwing pre-selector valve is used to operate the wing flaps and the angle of the flaps can be pre-set at any desired degree.

LANDING GEAR

The F4U landing gear is the semi-cantilever type. It consists of Vought-Sikorsky pneumatic shock struts to absorb the shocks of landing and taxiing and these struts are braced by drag struts which are locked in place by elbow locks. The elbow locks are off-center torque links which are unlocked by hydraulic pressure exerted through the landing-gear actuating cylinder. The landing gear is retracted hydraulically using a shaft oil pick-up type of actuating cylinder. When retracted, the landing gear moves aft and up into wheel wells in the wing.

Doors allow the wing to retain its contour after the gear is retracted. Each wheel well has two doors and each door has its own actuating cylinder. Sequence valves see to it that the doors close at the proper time. A sequence valve is located on the forward bulkhead of each wheel well to make sure that the doors close only after the landing gear has been fully retracted. In retracting, the landing-gear strut must contact the plunger of the sequence valve before fluid can be directed into the door actuating cylinders.

The landing-gear selector valve must be moved to the UP position to retract the landing gear. This selector valve is located on the lower left-hand side of the instrument panel in the cockpit. Manipulation of the valve releases fluid into the landing-gear working lines. This fluid pressure is directed through aluminum tubing to the sequence valve in

the wheel well. With the landing gear extended, the sequence valve is in the closed position so that pressure flows through the top channel of the valve forward into the shaft end of the actuating cylinder. Flow cannot enter the door actuating cylinders with the sequence valve in this position.

The first movement of the actuating cylinder unlocks the elbow lock and starts the landing gear moving aft. As the gear is retracting, a swivel joint causes the strut and wheel to turn approximately 87 degrees in order for the wheel to fit into the wheel well. When the gear is fully retracted, the elbow lock straightens out and locks the gear in the UP position. Reaching the full UP position, the strut contacts the plunger in the sequence valve, pushing the poppet off its seat and allowing pressure to enter the door actuating cylinders and close the doors.

Turning the landing-gear selector valve to the UP position also opens the tail-wheel selector valve. This directs the flow into the shaft side of the tail-wheel actuating cylinder, compressing the spring and raising the tail wheel. Unlike the main gear, the tail wheel is held up by fluid pressure only and the tail-wheel doors operate mechanically.

To lower the landing gear, turn the selector valve to the DOWN position. Fluid pressure is directed to the door actuating cylinders and landing-gear actuating cylinders simultaneously, but the doors open first because less pressure is needed to open the doors than to unlock the landing gear UP lock. Fluid entering the landing-gear actuating cylinder passes through a shuttle valve.

Purpose of this shuttle valve is to close off the emergency CO_2 during normal operation and, in emergency, to close off the fluid working line from the CO_2 pressure. The fluid enters the blank end of the actuating cylinder. The first movement of the cylinder again unlocks the elbow lock and

forces the landing gear down and forward. The landing gear again turns 87 degrees back to its proper position.

It is impossible to drop the landing gear by its own weight in case of failure of the hydraulic system because the gear must be forced forward against wind pressure. Therefore, an emergency system is required. In an emergency, the pilot pulls an emergency handle in the cockpit. This releases fluid pressure holding the landing gear in the UP position through two emergency release valves. These valves are Adel two-way poppet-type selector valves. Pulling the handle connects the UP working line to the return line thus releasing the fluid pressure that holds the landing gear in the UP position. Pulling the handle also releases the cutter knife in the CO_2 bottle, thus discharging one pint of CO_2 through the shuttle valves into the landing-gear actuating cylinders.

The CO_2 lowers the gear in the same manner as the regular hydraulic fluid does under normal operation. When this emergency method of lowering the landing gear is used, the doors of the wheel wells are opened by the weight of the gear dropping on them.

Pulling the emergency handle also opens the emergency release valve for the tail wheel. As the tail wheel is held up by fluid pressure alone, release of the pressure allows the tail wheel to extend. It is forced into the extended position by the spring-loaded actuating cylinder.

The purpose of the DIVE BRAKE is, as the name implies, to reduce the speed of the airplane in a dive. The braking action is obtained by extending the landing gear which offers resistance to the air. The gear can be extended at speeds up to 200 knots. The dive-brake control is on the left-hand side of the cockpit on the sub-instrument panel. Operating this control extends the main landing gear

but allows the tail wheel to remain in the retracted position.

WING FOLD SYSTEM

The WING FOLD system of the F4U folds the outer wing panels overhead. This is accomplished by the use of one actuating cylinder for each wing. The cylinders are located in the outer panels of the wings. The actuating cylinder is installed in such a position that, as the strut extends, the wings will gradually assume the folded position. The wings are locked in the "spread" or flight position by a hydraulically operated locking pin.

Fluid pressure must not enter the wing fold actuating cylinder until this pin has been withdrawn. Otherwise, binding of the locking pin would occur and it could not be withdrawn. Here again, a sequence valve sees that things happen in their proper order.

A manual lock pin must be released before the wings can be folded. This pin is a safety device which locks the wing lock cylinder to prevent accidental folding of the wings. Release of the lock starts an electric howler a'howling. Then the selector valve (located along with the manual lock on the left-hand shelf in the cockpit) must be turned to the FOLD position. This directs fluid to the wing lock cylinder. The fluid enters the cylinder on the shaft side of the piston and at the top of the internally contained sequence valve. As the sequence valve is closed, fluid cannot proceed farther but builds up pressure at the shaft end of the piston. This unlocks the wings and raises a flag.

The wing lock piston will then strike the sequence valve plunger, opening the sequence valve and directing the fluid pressure into the wing fold actuating cylinders on the blank end thus folding the wings. The howler ceases to howl after the wings have retracted approximately 7°. The re-

turn fluid from the shaft end of the actuating cylinders passes through two Bendix restrictors slowing the movement of the wings so as to prevent damage.

The selector valve must be turned to the "spread" position in order to spread the wings. The fluid flows to the load-and-fire, or sequence, valve in the leading edge of the wing stub and then into the shaft end of the wing-fold actuating cylinder, pulling the wings down to the spread position. The load-and fire valve will then be in the extended position, preventing fluid from entering the wing lock cylinders. The howler will sound when the wings have reached a point about 7° before spread position. As the wing panel reaches spread position, a striker pin contacts the load-and-fire valve directing flow to the blank end of the wing lock cylinder and locking the wing. This forces the warning flag down. Inserting the manual lock pin secures the wing in the locked position and stops the howler.

WING FLAPS

Because it is a high-speed, high-altitude fighter, the F4U uses its wing flaps as an aid to maneuverability. These flaps are operated by a Fleetwing pre-selector valve mounted on the forward left-hand side of the cockpit. By manipulating this valve, the pilot can lower the flaps to any desired angle from 0 to 50°. A flow divider, located in the cockpit on the forward bulkhead, equalizes the fluid flow to the flaps causing the flaps on either wing to operate together. A bypass valve is installed on the actuating arm of the starboard wing for use during "automatic flaps up" when wind pressure against the flaps becomes excessive.

Turning the pre-selector valve to the "flaps down" position, directs the fluid pressure to the bypass valve. When the airplane is on the ground

or when its speed is less than 120 knots, the bypass valve is in the extended position directing the pressure through a restrictor into the flow divider in the cockpit. The flow divider equalizes the flow which goes to the shaft end of the two flap actuating cylinders lowering the flaps. A relief valve built into the flow divider relieves thermal expansion at 1,850 psi.

Setting the pre-selector valve to the UP position changes the flow so that it goes directly into the blank end of both actuating cylinders, raising the flaps. The return fluid must now pass through the restrictor which prevents the flaps from closing too fast.

Speeds in excess of 120 knots would damage the flaps if they were extended a full 50°. Therefore, the flap system has an automatic feature whereby the maximum flap angle is determined by the speed of the airplane or—to be more specific—the wind resistance to the flaps. This ranges from a full 50° at 120 knots to 10° at 411 knots. The automatic operation is controlled by a bypass valve and a preloaded spring in the actuating arm of the stub flap which is located on the starboard wing of the airplane.

An airplane reaching a speed of 120 knots with full 50° flaps would have sufficient air pressure exerted against the flaps to compress the spring in the actuating arm. Compression of this spring will take up 0.005 inch to 0.010 inch clearance between the striker pin and the piston shaft of the bypass valve. Contact the striker pin with the bypass valve piston shaft closes off the pressure line from the selector valve and connects the shaft side of the actuating cylinders to the return line. This releases the fluid pressure holding the flaps down and allows them to rise. As the speed of the airplane is standardized and the flaps assume a "safe" angle, the bypass valve takes a neutral po-

sition maintaining only enough fluid pressure to hold the flaps at that particular angle.

Decreasing the speed of the airplane reduces the wind resistance on the flaps, allowing the spring-loaded actuating arm to extend. This will change the bypass valve to its original extended position, again directing pressure into the flap actuating cylinders and lowering the flaps.

ENGINE COOLING

Efficient operation of the airplane engine depends upon its proper cooling. Two radiators, located in the fuselage, cool the supercharged air coming from the engine and thus prevent preignition. Oil is cooled in radiators located in the leading edge of each wing. There must be a complete circulation of air through the honey-combs of these radiators to obtain proper cooling. This circulation is controlled by hydraulically operated shutters. Cylinder-head temperatures are controlled by the cowl flaps, also operated by hydraulics.

These units, the oil cooler shutters, the cowl flaps, the accessory compartment for cooling the supercharged air, and also the arresting gear are operated from the four-bank selector valve. The oil cooler, cowl flap, and accessory compartment selector valve handles are spring-loaded to neutral to prevent loss of system pressure through the relief valves in each of them.

Holding the oil cooler selector valve handle in the OPEN position directs fluid pressure through Bendix restrictors into the blank end of each of the oil cooler actuating cylinders and opens the shutters. To prevent full system pressure from damaging the actuating cylinders and shutters, a relief valve—set at 550 psi—bleeds off excess pressure to the return line. Release of the spring-loaded selector valve handle returns it to neutral.

Turning the selector valve to the CLOSED position directs fluid pressure into the shaft end of the actuating cylinder thus closing the shutters.

The accessory compartment shutters may be opened by holding the selector valve handle in the OPEN position which directs the fluid pressure into the blank end of the actuating cylinder. The maximum pressure in this line is 300 psi controlled by the relief valve.

Holding the spring-loaded handle in the UP position directs the pressure into the shaft end of the actuating cylinder, closing the accessory compartment shutter. The relief setting in this position is 550 psi.

The 18 cowl flaps are spring-loaded to the open position. Holding the selector valve handle in the CLOSED position directs the pressure through a restrictor into the shaft end of the actuating cylinder, pulling the cowl flaps closed through a cable and pulley linkage. The cable acts as a draw string in pulling the flaps to the closed position.

Turning the selector valve to the OPEN position extends the strut allowing the cable to slacken and permitting the spring to open the flaps.

External air pressure against the cowl flaps, if open, will overcome the spring load in the flaps at 175 knots indicated air speed and force the flaps toward the closed position. The degree of closure will increase in proportion to the air speed.

At 322 knots indicated air speed, internal air pressure against the system—and consequently against the system—will build up a back pressure at the cowl flap actuating cylinder of 750 psi. At this point, the relief valve in the pressure line will bypass the hydraulic fluid to the return line and permit the flaps to open.

Turn the selector valve to the UP position to retract the arresting hook. This directs the pressure to the shaft end of the actuating cylinder

compressing the spring-loaded strut and raising the hook. A pressure of at least 250 psi is required to hold the hook in the UP position. For this reason, the arresting hook selector valve is somewhat different from others used in the system. Either an extra-heavy spring or a balanced piston is used in this selector valve to hold a back pressure of 400 psi, which is enough to hold the arresting hook up.

Turn the selector valve to the DOWN position to extend the arresting hook. This releases the fluid pressure holding the arresting gear up and allows it to be lowered partly by its own weight and partly by the spring-loaded dash-pot assembly. With the hook extended, the dash-pot assembly prevents the hook from bouncing up from the deck when making a landing.

The mechanical linkage at the banked selector valve is arranged so that the arresting hook control cannot be thrown into the DOWN position with the landing gear control in the UP position.

In addition to these units, three guns in each wing are hydraulically charged. Two gun-charger valves, located on the forward left-hand auxiliary panel, each operate three of the gun-charger cylinders. The red tip of the handle tells whether the guns are in the "safe" or "charged" position. The gun-charger cylinders are single-acting, spring-loaded actuating cylinders. Three are located in the outer panel on each wing. The piston shaft operates the gun bolt.

Turning the gun-charger valve to the CHARGE position and pushing it in directs the flow into the blank end of the gun-charger cylinder compressing the spring and forcing the bolt back. Pressure builds up in the cylinder and valve to approximately 750 psi, at which point the gun-charger valve will snap open releasing the fluid pressure to the return. The spring-loaded cylinder releases the bolt and the gun is charged.

The gun-charger valve may be turned to the SAFE position and pushed in. This operates the same as before with the exception that—when pressure builds up to 750 psi and the gun-charger valve snaps open—the fluid pressure will be locked in the gun-charger cylinder holding the bolt of the gun retracted. In order to fire the guns, the gun-charger valves must first be turned to the CHARGE position.

The brake system consists of Goodyear multiple-disk brakes operated hydraulically by Vought-Sikorsky master cylinders.

CHAPTER 8

THE SBD DAUNTLESS

HYDRAULIC SYSTEM DETAILS

The hydraulic system on the SBD 3, 4, and 5 is quite simple in design, layout, and function, but several of its units differ from usual hydraulic equipment. The most unique difference is that this system does not use a pressure regulator or accumulator. Instead, a TIME-DELAY VALVE directs and regulates pressure.

When none of the actuating units are in operation, the time-delay valve is in the OPEN position allowing the fluid from the pump to go directly to the Sperry relief valve. This valve acts as a regulator in that it will allow only 120 psi to pass into the automatic pilot system. When pressure surges, caused by such conditions as sudden increases in r. p. m. or starting cold engines, exceed 120 psi, the valve meters 120 pounds to the autopilot system and the relief valve opens and dumps the excess hydraulic fluid back into the reservoir.

HERE'S HOW YOU OPERATE THE SYSTEM.

First make the selection you need. At this point there is a maximum of 120 pounds pressure going through the selector to the unit to be actuated. This is insufficient for operation so the time-delay valve is closed. This blocks off the line from the delay

valve to the reservoir and directs pump pressure to the selected actuating cylinder. Now you get a rapid pressure increase to about 1,050 psi, enough to actuate the cylinder. The operating time of the time delay valve is 20 (plus or minus 5) seconds. When the valve reaches the end of its cycle, it opens and allows fluid from the pump to go to the auto pilot and reservoir. A check valve in the line holds the system pressure in the selected unit. The landing gear incorporates a mechanical latch to insure against a possible ground retraction or flight extension.

On airplanes that are equipped with auto pilots, fluid flows into the time-delay valve through the inlet, past the main cut-off valve and into the line to the Sperry relief valve. On airplanes without the auto pilot, the fluid flows to the reservoir through the restrictor valve and return line. To operate the time-delay valve, push the handle down completely. This simple operation causes the piston to push the valve nut down and forces the valve onto the seat thereby closing off the system. With the valve closed the system builds up rapidly to 1,050 psi. The cup packing is designed to allow the fluid in the chamber below the piston to bypass the piston on the down stroke.

This chamber on the top side of the piston—and the chamber for the metering rod—are filled with fluid. The large chamber is ported through to the metering chamber by a small orifice at the top of the main chamber. Pressure from the pump holds the valve closed because of the pressure differential on either side of the valve.

The valve nut is not a tight fit so that pressure from the pump can flow by and bear on the bottom of the piston to force it up. As the metering chamber and the chamber above the piston are full of fluid, the rate at which this fluid is allowed to exit to the return system affects proportionately

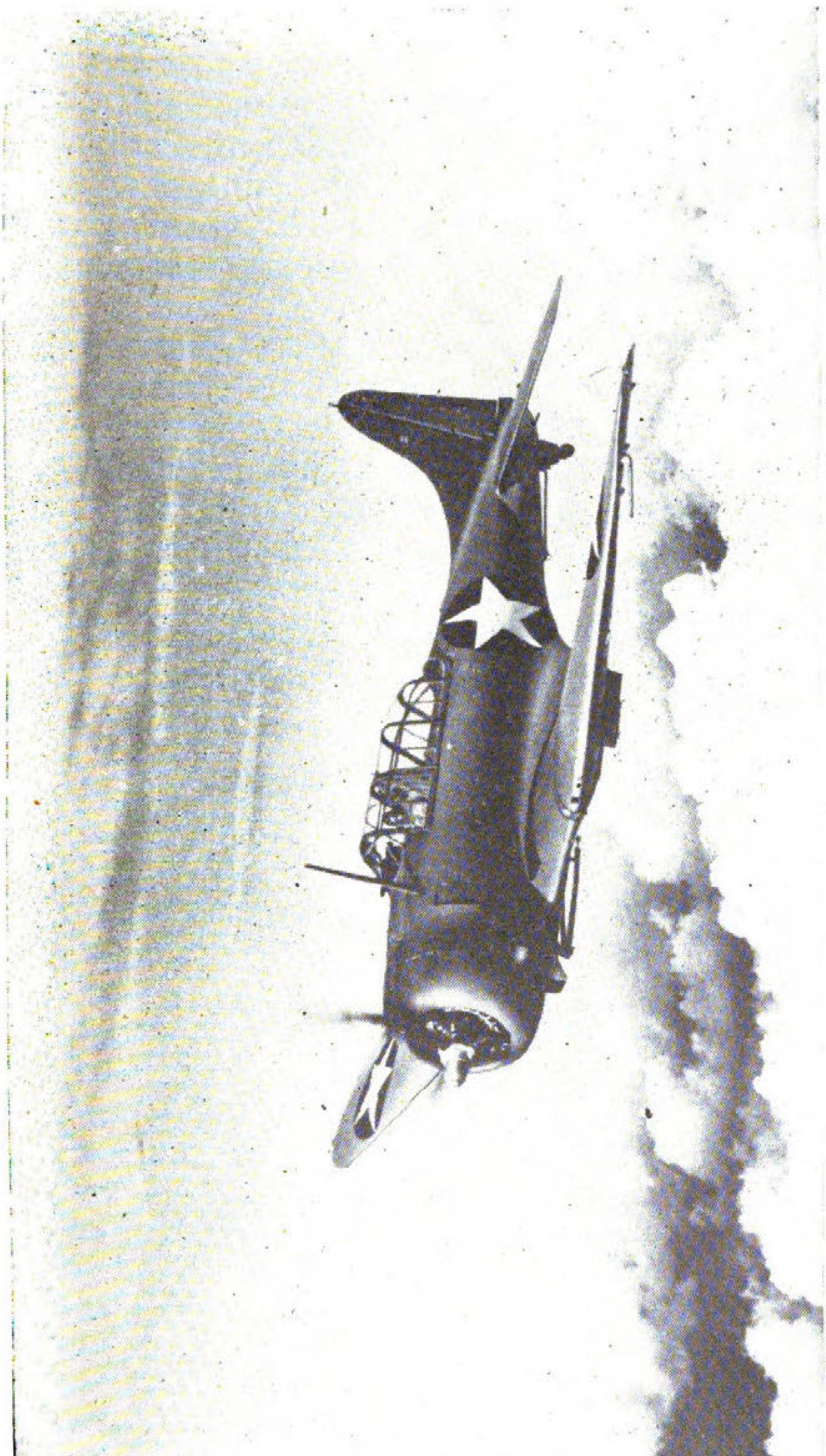


Figure 61.—The SBD Dauntless.

the back pressure on the top side of the piston. This regulates the speed with which the engine pump pressure can force the piston to return to a normal position. When the piston nears the end of its up travel, the hollow cylinder and spring retainer return with it and make contact with the bottom side of the valve nut. The valve is pulled open and a cycle of the time-delay valve is completed.

The relief valve is set to start relieving at a pressure of 1,050 (plus or minus 20) psi. The operating time of this valve is regulated by the metering rod which is obtainable in several lengths and diameters. Increasing its length and/or diameter lengthens the time of operation. Decreasing length or diameter shortens the time. This compensates for various fluid viscosities and friction within the mechanism of the valve.

LANDING GEAR

The landing gear is a full-cantilever, single-strut type. It is hydraulically operated and fully retractable. When retracted, the gear is housed in the wing center section. The landing gear struts can be compressed partially as the gear is retracted.

The Bendix single oleo pneumatic struts are attached rigidly to torque shafts. Rotation of the shafts retracts the gear by swinging the wheels and struts inboard and up into the wing center section. The torque shafts are operated by individual hydraulic cylinders connected to arms on the shafts. A selector valve knob, located on the erates the selector valve for directing the fluid flow right side of the cockpit, unlocks the gear and op- to extend or retract the landing gear.

The landing-gear emergency relief valve is the needle type and it connects the landing gear UP line to the system RETURN line. If any of the land-

ing-gear hydraulic units go on the "fritz," this valve is opened to dump the fluid and allow the gear to extend by gravity and lock in the DOWN position. The emergency relief valve should be on SAFETY at all times. As the landing-gear selector valve operates the cam to "break" the gear by a cable connection, it must be moved to the DOWN position to release the gear from the mechanical latch.

The tail wheel is not retractable.

The LANDING AND DIVING FLAPS ACTUATING CYLINDER is a cylinder within a cylinder because the landing flap piston operates within the diving flap piston. The landing flap piston must never be operated in conjunction with the diving flap piston. It should be operated only with the diving flaps closed, as operation of both units can cause severe damage to the flap mechanism.

LANDING FLAP OPERATION

Pressure enters the pressure side of the piston through the hollow center and forces the piston out and the landing flaps to their DOWN position. When the flaps are closed, pressure enters the rear of the piston and its hollow center becomes the return.

DIVING FLAP OPERATION

As the diving flap cylinder contains the landing flap cylinder, an inch travel on the diving flap cylinder will result in an inch travel on the landing flap cylinder. Pressure entering the aft end of the diving flap cylinder will force the cylinder to extend and open both the diving and landing flaps an equal amount. When the flaps are closed, the pressure is reversed and the cylinder returns to its closed position.

SEQUENCE VALVE

The force required to operate the diving flaps necessitates a large actuating cylinder—thus the

returning fluid has a high velocity during the closing operation. Because the small ports in the selector valve would have a metering effect on the return fluid, a sequence valve is installed in the system to bypass the selector valve and provide the fluid with an additional return to the reservoir.

The sequence valve is actuated mechanically when the dive flap selector handle is in the closed position. It is spring-loaded to close when the selector handle is in the neutral or open position. When the booster cylinder is under pump pressure, the sequence valve also acts to block off the cylinder lines from the return system.

BOOSTER CYLINDER

Because the force required to operate the diving flaps is greater than the pump is able to develop, a booster cylinder is installed between the selector valve and the actuating cylinder. The booster cylinder utilizes the hydraulic principle of relative areas which you read about in the first chapter. It consists of a cylinder and a hollow piston. An additional cylinder, attached to the bottom of the main cylinder, fits into the piston. The area of the outside of the piston is greater than the area on the inside (pressure surface only) and their ratio is designed to give a pressure boost of 2.7 to 1 across the booster cylinder.

When the pressure enters the cylinder, it forces the piston down and pressurizes the fluid within the piston to this ratio. The piston is spring-loaded to aid in its return when the dive flap actuating cylinder is closing. A small check valve in the head of the piston is unseated by a pin in the main cylinder head when the piston is returned to its normal position. This will kill any left-over pressure in the booster system, and also insure that the high-pressure side of the booster system will be adequately supplied with an initial amount of dis-

placeable hydraulic fluid. It also takes care of any loss due to leakage from loose or worn fittings.

ENGINE COWL FLAP SYSTEM

The cowling flap selector valve (Adel poppet type) has a relief valve (Manufacturers Acces-

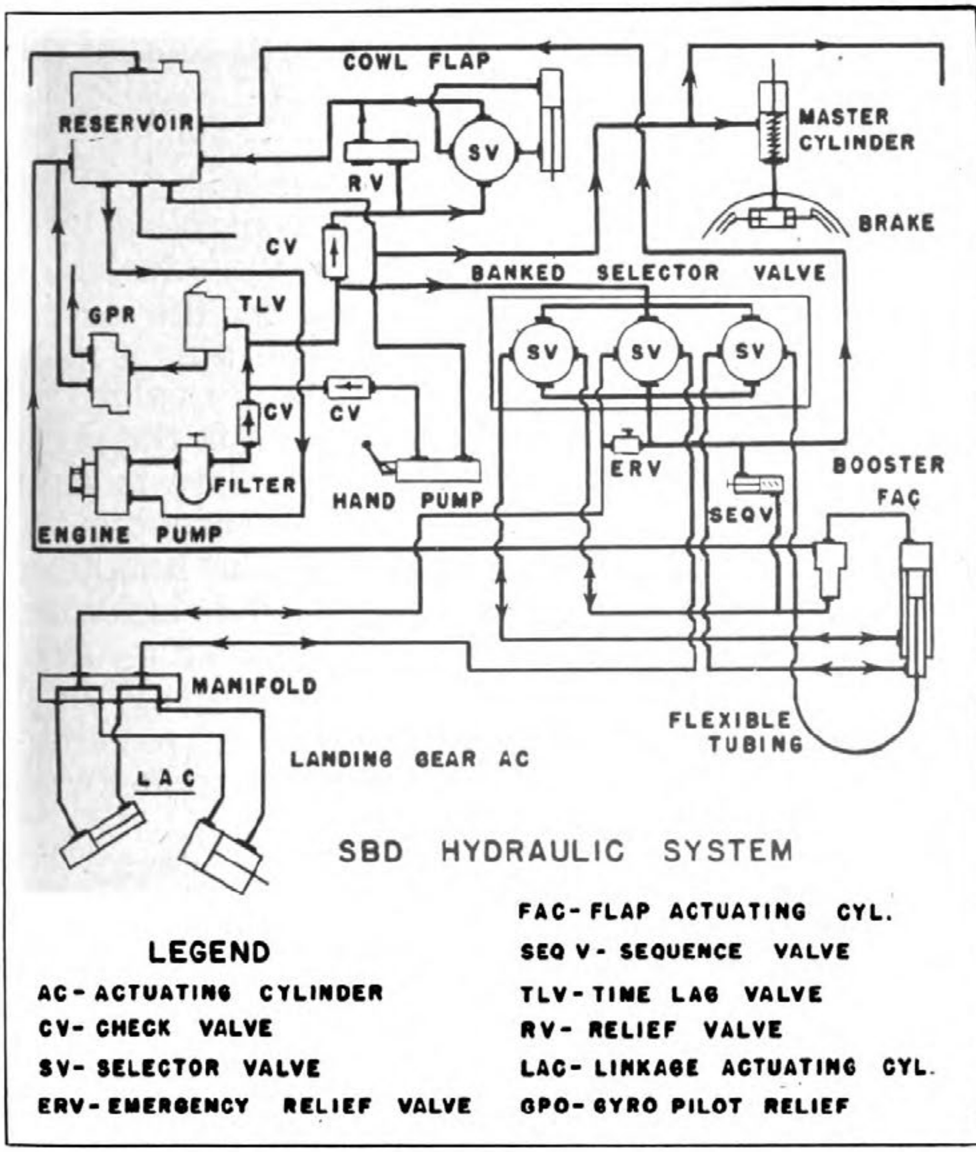


Figure 62.—Flow diagram of the SBD hydraulic system.

sories Corporation) set to hold 1,350 (plus 50, minus 0) psi. This valve lever handle, located on the left side of the pilot's cockpit, directs the flow for opening or closing the engine cowling flaps. To

operate the cowling flaps, move the selector valve lever to the OPEN or CLOSED position and operate either pump. A neutral position is provided so that the flaps can be held at any point desired by the pilot of the airplane.

The actuating cylinder for the cowl flaps connects to the bottom of the flap operating link ring and moves the flap control rods which control the cowling flaps.

BRAKE SYSTEM

Each Hayes duo-servo brake is controlled by a Bendix hydraulic brake-operating unit which is connected individually by linkage to the corresponding brake pedal. Each unit contains a master cylinder, piston, and parking-brake valve.

The parking-brake handle is located to the right of the pilot's instrument panel. Pressure is built up in each master brake cylinder by pressing the brake pedals. When the parking-brake handle is pulled out and turned one-quarter turn clockwise, the brakes are set and locked by the parking-brake valve. The brakes are released by applying pressure to the brake pedals, turning the parking-brake handle one-quarter turn counterclockwise and returning it to the IN position.

TRICKS OF THE TRADE

HYDRAULIC RESERVOIR FILLING—

Use mineral oil only. (M–339 or AC–3580.)

Be sure the oil is clean.

Fill to "full" mark on reservoir gage glass with dive flaps open and landing gear down, cowl flaps open, and landing flap selector valve handle in the "closed" position.

Screw filler cap down tightly when finished.

The reservoir filling cap is on the right-hand side of the fuselage.

UNIT POSITIONS BEFORE NORMAL LANDING—

System operating on engine pump pressure; time-delay valve closed.

Landing gear down.

Landing flaps open.

Diving flaps closed.

Cowl flaps partly open.

UNIT POSITIONS DURING NORMAL DIVE—

System operating on engine pump pressure; time-delay valve closed.

Dive flaps open. (All five surfaces.)

Landing gear up.

Cowl flaps closed.

Landing flap operating handle in closed position.

SYSTEM DATA

Operating pressure is 1,000 psi.

Total system capacity is 2.5 gallons.

Capacity of reservoir is 0.64 gallon.

Fluid used—mineral oil, M–339 or AC–3580.

Pesco engine driven gear pump—

Condition	Engine R. P. M.	Pump R. P. M.	Pump Outfit (G. P. M.)
Take off	2,350	3,525	3.60
Cruising	1,850	2,775	2.75
Idling	550	825	.60

Purolator filter, relief valve set at 120 psi.

Time-delay valve—when depressed, closes fluid flow to auto pilot and return, allowing pressure to rise in the main pressure line for actuation of units.

Relief valve for Sperry unit set at 120 psi.

There are three check valves.

There are two relief valves. One in the time-delay valve is set at 1,050 psi and one at the cowl flap system is set at 1,350 psi.

Cowl flap selector valve is the Adel poppet type.

Three rotary plug-type selector valves for flaps, one for landing gear and dive flaps.

Adel double-acting hand pump—displacement 1.5 cubic inches per cycle.

Bendix three-chamber cylinders fed from main system reservoir for operation of brakes.

Hayes single-shoe, duo-servo brakes.

Sequence valve in dive flap system is used to facilitate a speedy return in dive flap closing operation because a check valve in the selector valve tends to restrict flow.

The booster cylinder ratio is 2.7 to 1.

Units operated hydraulically are—

Landing gear.
Landing flaps.
Diving flaps.
Cowl flaps.
Auto pilot.
Brakes.

CHAPTER 9

THE TBF–1, AVENGER

HYDRAULIC SYSTEM DETAILS

The efficient operation of the Avenger as a torpedo bomber depends a good deal upon the proper functioning of its hydraulic system which is directly, and indirectly, responsible for the operation of all its major units including the landing gear, wing flaps, bomb-bay doors, wing fold, cowl flaps, oil cooler and brakes. All of these units are operated from the main hydraulic system on this airplane with the exception of the brakes.

Again beginning where the hydraulic fluid begins, the power system is the first to be considered. It supplies, induces, regulates and distributes fluid under pressure to all operating units in the system, and is composed of the reservoir, engine pump, filter, pressure regulator, main relief valve, and pressure accumulator. These units, with the exception of the pump, are located on a panel forward of the electric turret in the fuselage.

The RESERVOIR supplies fluid to the engine pump through a 1-inch suction line. It has a capacity of 1.6 gallons and is filled with mineral oil, Navy specification M–339.

The ENGINE PUMP is a Vickers 7-piston constant-displacement pump. Displacement is 0.410 cubic

inch per revolution. It is connected to the accessory section of the power plant and is used to induce fluid flow.

The PUROLATOR FILTER is installed in the pressure line and is composed of several fine meshes of monel wire. It cleans and filters the fluid.

A PRESSURE REGULATOR maintains system pressure between 1,150 psi cut-in and 1,500 psi cut-out. It is the Electrol balanced type and unloads the pump when nominal operating pressure is reached.

The MAIN PRESSURE-RELIEF VALVE safeguards the system in the event the pressure regulator fails to cut-out. It is set to relieve the pressure at 1,750 psi.

The PRESSURE ACCUMULATOR is a 5-inch Vickers model with an oil capacity of 31.5 cubic inches. It absorbs shocks in the system, aids the engine pump at peak demands, increases operating efficiency of the regulator and stores fluid under pressure for emergency operation of at least one unit.

After passing through the power system, fluid under pressure is distributed via the main pressure line through four individual lines each of which has a thermal relief and check valve. The four lines are connected to the hand pump selector valve and each line carries fluid to its respective selector valve. Pressure is recorded by the system pressure gage and pump pressure gage located at the right-hand side of the bottom of the cockpit. The hand-pump selector valve, being open to any one of the four lines, makes the reading on the system gage possible.

Snubbers at the gages prevent rapid fluctuation of the needles because of rapid change in pressure during operation. A check valve installed after the hand pump prevents system pressure from acting on it.

The selector valves are the Electrol balanced poppet type. With the exception of the bomb-bay

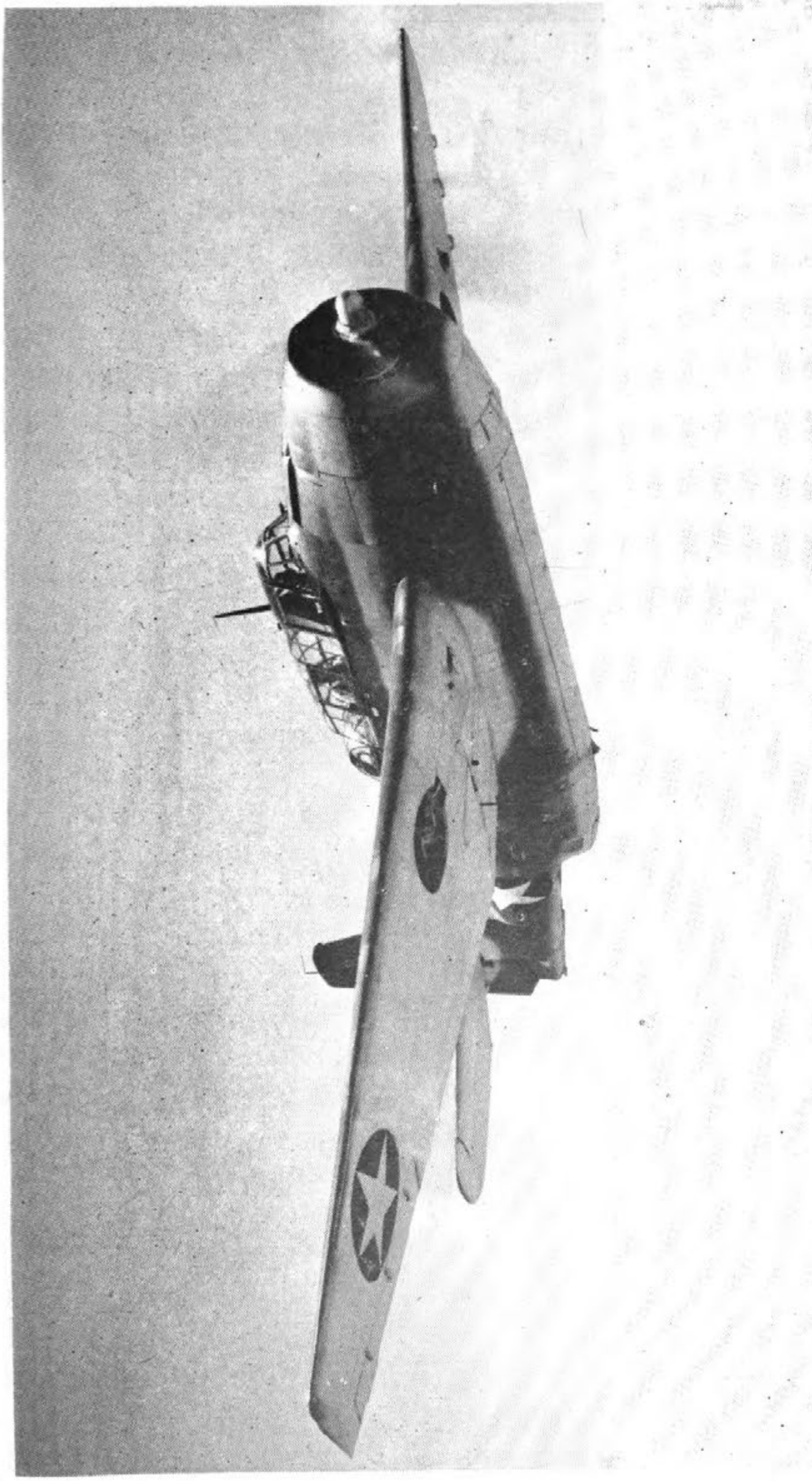


Figure 63.—The TBF, Avenger.

selector valve which is located under the floor of the 2nd pilot's cockpit, all are located in the main cockpit. With the selector valves in neutral, fluid pressure rises to 1,500 psi, at which time the pressure regulator cuts out to unload the pump and direct the pump flow to the reservoir by way of the common return line. At this point, the pump pressure gage drops to zero and the system pressure gage maintains a reading of 1,500 psi.

In the event of power system failure, an emergency hand pump and hand-pump selector valve can be used for the operation of any unit in the system. The hand pump is an Electrol double-acting model with a displacement of 1 cubic inch per cycle. It is located on the right side of the cockpit.

The four positions on the hand pump selector valve are—

Bomb bay
Landing gear
Wing flap
General—Wing fold
Oil cooler
Cowl flaps

The hand-pump intermediate relief valve and the four thermal relief valves prevent hand-pump pressure from exceeding 1,750 psi. The four check valves stop fluid flow from entering the pressure accumulator in the power system. When the hand pump is not being used, the hand-pump selector valve should be in the general position.

WING FOLD

First step in folding the TBF wings is to release the spring-loaded toggle located on the right side of the instrument panel. This hand-operated toggle is connected to a mechanical pin located at the wing lock cylinders. The pin is used to prevent creeping of the hydraulic wing lock pin.

As the mechanical pin is released, it contacts a micro-switch which sounds the howler and warning horn. A flag, connected to the pin, will appear above the skin on the upper camber of the wings. These indicators tell the pilot that the hydraulic lock has been unlocked.

The selector valve is turned to WING FOLD. Hydraulic fluid under pressure is then introduced into the flow equalizer in the bomb bay. This equalizer distributes oil in equal volume to each wing so that they are moved simultaneously.

After passing through the flow equalizer, the fluid enters the wing flap timing valve. Because of the construction of the wing fold feature and its movement to the full fold position, it is possible to damage the wing flaps if they are down. To avoid this, the timing valve is installed in the unit. When the flaps are in their full retracted position, the timing valve pin is contacted and fluid flows freely to the wing lock cylinder. If the flaps are partly down—the pin of the sequence valve is released. This allows the poppet to seat, preventing fluid flow and consequent unlocking of the wing.

Fluid enters the wing lock cylinder through port 1. Fluid acting on the cup piston overcomes the spring-loaded detent arrangement holding the lock out. The movement of the piston pulls the pin out of the wing and, at the same time, uncovers port 2 which directs the flow to the cylinders. This sequence arrangement prevents fluid from entering the wing fold cylinders before the wing is fully unlocked.

As the wing is unlocked, it drops immediately to the sag position pulling the piston in the stub cylinder. The wing drops with leading edge down, turning sideways. In this position, the howler which started blowing upon release of the mechanical pin is stopped by the contact of a micro-switch riding on a cam at the wing hinge point. Since the

piston in the inboard cylinder cannot move, the fluid under pressure acts on the cylinder in the folding panel which is attached to the wing and thus moves it to the fold position. The wings are held back by the fluid under pressure or by cables in each wing tip.

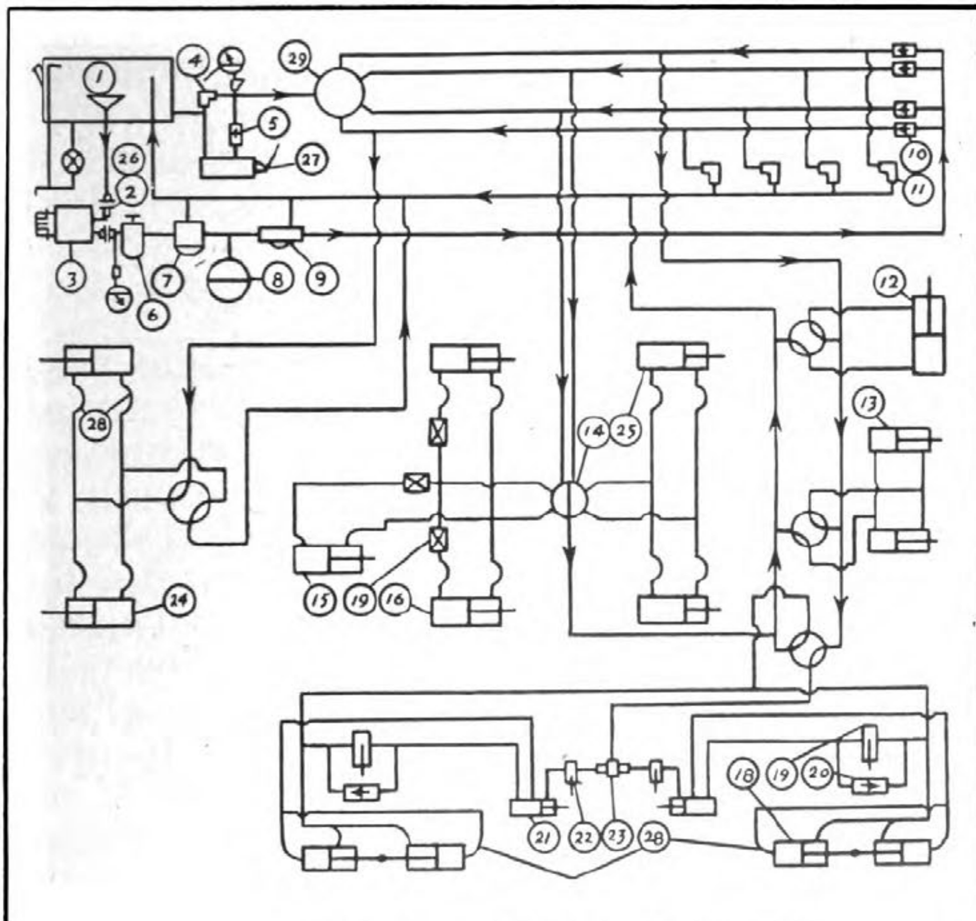
The two wing folding cylinders for each wing are located half way on the mean aerodynamic chord of the wing and are inter-connected by pistons and piston rod. Two cylinders are required to facilitate full throw of the wing from the spread to fold position.

In case of hydraulic system failure, the wings can be unlocked manually. The manual handle on the wing lock shaft adapter is pushed forward to remove the lock. Fluid that is entrapped in the wing lock is forced out of the check valve and timing valve and the lock pin can move freely.

WING SPREAD

To spread the wings for flying position, the wing tip cables are first removed and the selector valve placed at SPREAD. Fluid under pressure is directed into the inboard ends of both actuating cylinders. A check valve and wing-locking time valve are also subjected to this pressure. The fluid flow is stopped at these units and—as the fluid naturally follows the course of least resistance—the wings are free of pressure and will move to the sag position. At this point, the switch on the hinge point is released and the howler starts.

The wings continue to move to the full spread position by cylinder and piston actuation. As the wing approaches the full spread position, an adjusting striker screw on the leading butt end of the folding panel strikes the pin on the wing-locking timing valve, releasing fluid under pressure. Fluid acting on the piston in the wing lock cylinder locks the wings. Detent balls fall into



1. Reservoir.
2. Quick disconnect.
3. Engine pump.
4. Thermal relief valve.
5. Check valve.
6. Filter.
7. Regulator.
8. Accumulator.
9. Main system relief valve.
10. Check valve.
11. Thermal relief valve.
12. Oil-cooler actuating cylinder.
13. Cowl flap actuating cylinder.
14. Landing gear and wing flap selector valve.
15. Tail wheel actuating cylinder.
16. Main landing gear actuating cylinder.
17. Restrictor.
18. Wing fold actuating cylinders.
19. Wing lock timing lock.
20. Check valve.
21. Wing lock cylinder.
22. Wing fold timing valve.
23. Flow divider.
24. Bomb-bay door actuating cylinders.
25. Wing flap actuating cylinders.
26. Drain valve.
27. Hand pump.
28. Note: Curved lines show flexible tubing.
29. Hand pump selector valve.

Figure 64.—Diagram of the hydraulic system on the TBF.

their corresponding grooves to assure locking of the wing in the spread position. The mechanical pin is then pushed into position from the cockpit. Disappearance of the flag and silencing of the howler assure the crew that the wings are locked and the airplane is ready for the air.

LANDING GEAR AND WING FLAPS

The landing gear and wing flap selector valves are located on the left side of the instrument panel. The large square-knob lever is the landing-gear control, and the large round-headed lever to the right is the flap control. As these systems are usually operated together, the unit is designed so that—if the landing gear has not been lowered already—the lowering of the wing flaps also lowers the landing gear. The wing flaps can be operated independently of the landing gear, however, by pressing a small button on the wing flap lever. If both landing gear and flaps are down and it is desired to raise the landing gear only, a lock lever located to the left of the gear handle must be raised. This situation is likely to occur when making an emergency landing on water, when it is desirous to have the flaps down and the landing gear up.

To raise the flaps when the landing gear and flaps are down, you merely return the flap handle to the UP position.

RETRACTING THE LANDING GEAR.

The landing gear on the Avenger is retracted by placing the selector valve handle at the UP position. Fluid pressure is released and directed through three restrictors to all actuation cylinders. The restrictors prevent the gear from moving too rapidly. Reduced flow therefore enters the actuating cylinders located in the leading edge of the wing perpendicular to the chord line. The actuating cylinders are the floating type mounted on a

roller support to allow free movement in the forward and aft directions.

The piston and piston rod of the cylinders are connected directly to the oleo strut through a linkage. The strut is semi-cantilever and is held down by a diagonal locking strut. There is a lock at the elbow or breaking point. As the fluid enters the actuating cylinder, its pressure is exerted on the piston and cylinder head with equal force. However, only the cylinder moves because the piston is held stationary by the oleo strut which is locked in the DOWN position by the drag strut.

The cylinder in moving back turns the roller support, pulling a strut 3/4 of an inch. The unlocking strut is attached to a bolt in a slot overriding a cam which is a part of the horseshoe latch, located at the breaking point of the drag strut. As the cam is forced down by the sliding bolt, the latch immediately lifts off the hook, releasing a micro-switch of the throttle warning system and unlocks the drag strut. Then, fluid pressure in the cylinder, acting on the point of least resistance, forces the piston out and retracts the gear. The landing gear is held up by fluid pressure and a spring-loaded J-hook operated by the actuating cylinder. The movement of the gear is transmitted to the pilot's indicator by cable linkage.

TO EXTEND THE LANDING GEAR—

In the extension of the landing gear, the selector valve is placed in the DOWN position, releasing fluid pressure into the down line to the actuating cylinders. The initial movement of the cylinder unlocks the J-hook and releases the gear. Upon release, the gear drops freely under its own weight and fluid pressure. Restrictors again prevent a too-rapid movement of the gear. Springs in the actuating cylinders assist in moving the gear the last few inches to the locking position. Failure of the latch

to lock in the DOWN position will cause a howler or horn to blow as the throttle is pulled back to 1,200 rpm. Two micro-switches, one operated by the down latch—the other by the throttle arm—are responsible for this action.

EMERGENCY OPERATION—

When necessary, the landing gear can be extended by pulling an emergency dump valve on the left side of the instrument panel. This action releases the J-hooks and opens the return poppets in the landing-gear selector valve. This allows the gear to drop and forces the exhaust fluid in the cylinder through the selector valve to the reservoir. A spring-action safety device to prevent the gear from retracting accidentally is located at the scissors on the left strut.

BOMB-BAY DOORS

The bomb-bay door system consists of two positive locking type actuating cylinders located forward and aft in the bomb bay and one Electrol poppet-type selector valve located under the floor of the 2nd pilot's compartment. The doors can be operated by the pilot or the bombardier in the tunnel through an interconnection at the selector valve.

The doors are locked in the open and closed positions by hydraulic locks in the cylinders. Interconnecting cables at the actuating cylinders allow the doors to move simultaneously.

WING FLAP SYSTEM

By placing the selector valve handle in the FLAPS DOWN position, fluid pressure is directed into a restrictor which limits the volume of fluid entering the two actuating cylinders and thus slows the movement of the flaps. The flaps move down to a maximum angle of 50 degrees.

The flaps are retracted by placing the selector-

valve handle at UP. This reverses the fluid flow and allows the flaps to retract. Flap movement is transferred to a mechanical indicator in the cockpit by cable.

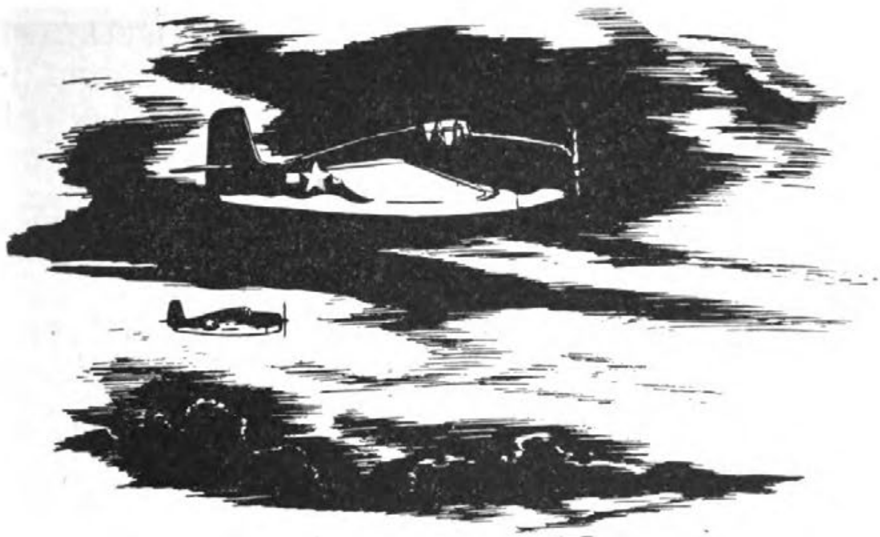
The flaps can be extended to any desired angle by holding the selector-valve handle at the DOWN position until the desired angle is reached, then moving the handle to neutral. This traps fluid on each side of the piston and the flaps will remain at that point.

OIL COOLER AND COWL FLAPS

The oil-cooler shutter system consists of one double-acting actuating cylinder and an Electrol poppet selector valve. Its purpose is to admit free circulation of air through the oil-cooler radiator for cooling the oil at high temperatures.

The cowl flaps system has two actuating cylinders, a restrictor, and one poppet-type selector valve. The cowl flaps regulate the cylinder-head temperature of the engine by admitting and stopping airflow past the cylinder heads and baffles of the engine. The cowl flaps can be opened to any desired extent in the same manner that the wing flaps are controlled.

Both the oil cooler and the cowl flaps systems are controlled by the pilot.



CHAPTER 10

THE F6F–3, HELLCAT

HYDRAULIC SYSTEM DETAILS

The hydraulic system on the Grumman Hellcat actuates the retractable landing gear, the wing flaps, wing lock, cowl flaps, oil-cooler shutters, intercooler flaps and the gun chargers.

The power system has an operating pressure of 1,500 psi and uses a red-colored hydraulic fluid which bears the code AN–VV–O–366A. Total capacity of the system is 4 gallons and reservoir capacity is 2.204 gallons. The reservoir is located on the right-hand side of the firewall just above the hydraulic distribution panel and is secured to the wall with metal straps.

A finger strainer is located in the filler neck of the reservoir to strain all fluid added to the system. This strainer is removed from the reservoir only for cleaning purposes. The induced flow of hydraulic fluid from the reservoir goes forward through a quick-disconnect fitting at the forward firewall to the intake port of the engine pump.

This pump is a Vickers 7-piston constant-displacement model. It displaces 0.200 cubic inch per revolution from the outlet port of the pump through another quick-disconnect to the Purolator filter. This filter is equipped with a relief valve which will bypass the fluid if the filter is clogged and thus continue the flow to the system.

The flow goes on to the Electrol poppet-type relief valve which is set at 1,750 psi. The return line "tees" into the pressure regulator return line to the reservoir. The pressure line continues on to the Electrol pressure regulator. The regulator has an operating range of 250 psi. It cuts-in (diverts flow to the system) at 1,250 psi and cuts-out (diverts flow back to the reservoir) at 1,500 psi. The flow continues to the Vickers 5-inch accumulator which has an air preload of 1,200 pounds.

From the accumulator, the pressure line continues on to a Kenyon check relief manifold which is located on the rear cockpit bulkhead, behind and to the right of the pilot. From this manifold, fluid is distributed to four pressure lines. These are—

The SYSTEM LINE which is an open line that allows the accumulator to be charged by the hand pump.

The LANDING GEAR LINE.

The WING FLAP LINE.

The GENERAL LINE which furnishes flow to the gun charger, cowl flap, oil and intercooler shutters, and wing lock-cylinder selector valves.

A thermal-relief valve set at 1,750 psi and a check valve are installed in the check-relief manifold of all lines except the system line. These pressure lines tee off to the various selector valves, go to and through the hand-pump selector valve to a system pressure gage, and stop at the hand pump. System pressure, which is 1,500 psi, is now trapped in all the lines up to the various selector valves, between the pressure regulator and the hand pump.

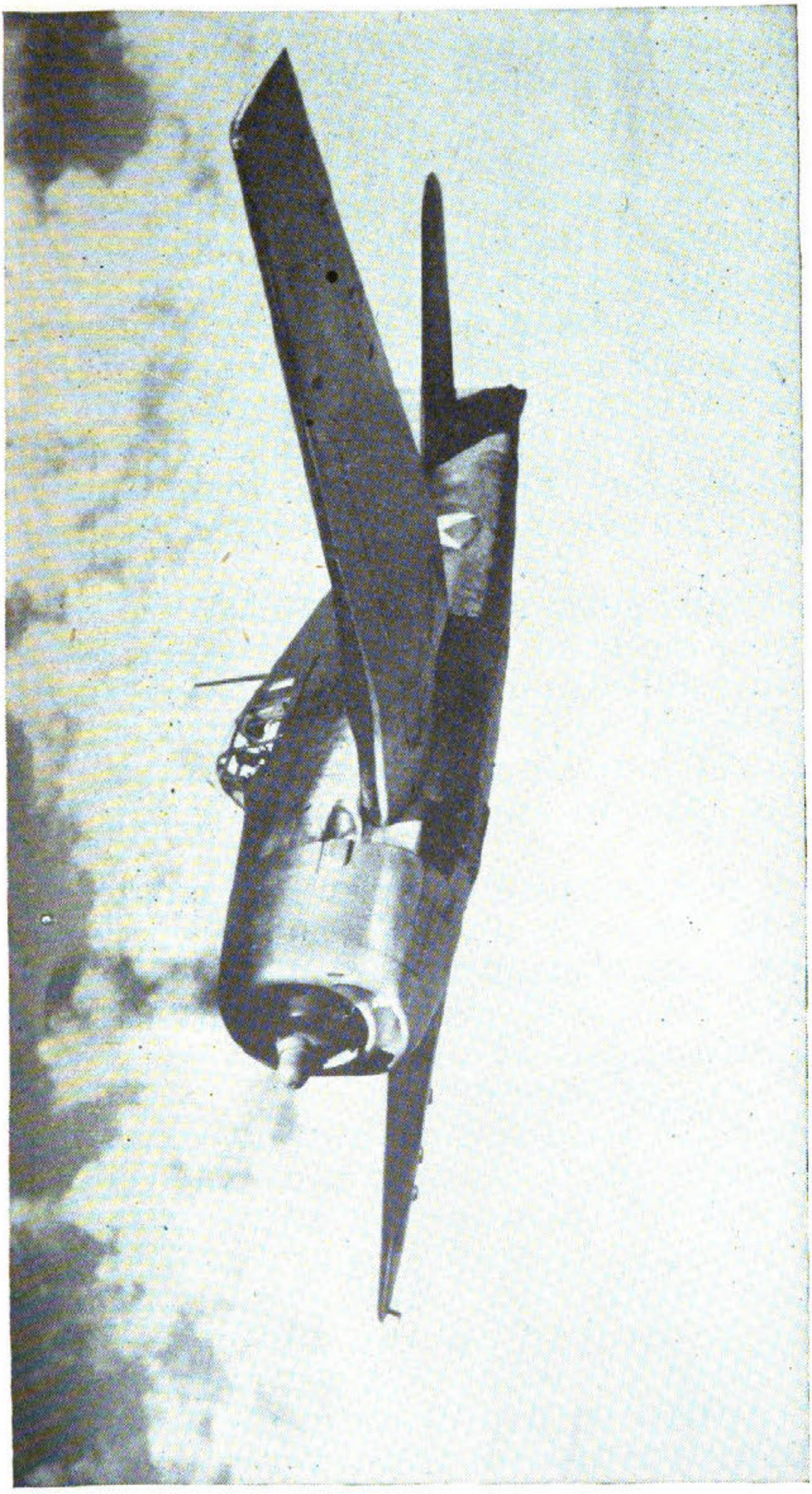


Figure 65.—The Grumman Hellcat.

This pressure is indicated on the system pressure gage.

For hand-pump operation, the hand-pump selector valve can be set at WING FLAPS, LANDING GEAR, or GENERAL. By making this selection, hand-pump flow is sent directly to the selector valve controlling the selected unit and is stopped by the check valves in the Kenyon check relief manifold, eliminating charging any extra lines. This decreases the amount of fluid needed for an emergency operation and also cuts down work and time.

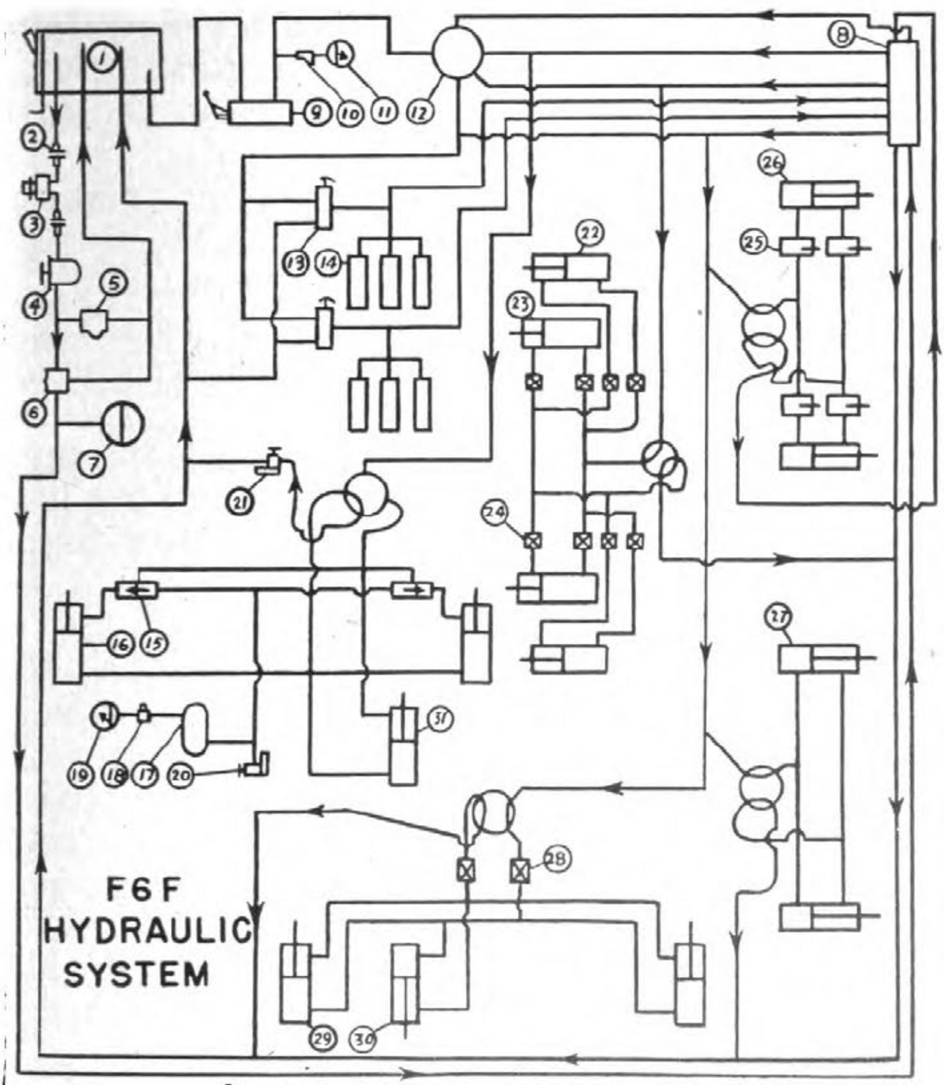
The accumulator can be charged by the hand pump by placing the hand-pump selector valve in system position. Remember that there is no check valve on the system line in the check-relief manifold.

The hand-pump selector valve has one common outlet to the hand pump and a system pressure gage is installed in this position. The selector valve is an Electrol poppet-type valve constructed so that the hand-pump line is always open to the position selected (system, landing gear, wing flap or general).

It is recommended that the hand pump selector valve be left at the SYSTEM position whenever the engine pump is supplying pressure. This assures a correct reading of operating pressures on the system pressure gage at all times.

GUN-CHARGING SYSTEM—

The right and left gun-charging valves are secured under the instrument panel and control the right and left gun-charging struts, respectively. They get their pressure supply directly from the general pressure line. Each gun-charging valve (made by Bendix) has two positions—SAFE and FIRE. When it is in the SAFE position and the handle is pushed in, fluid flows to the gun-charging struts and charges the guns. When a pressure of 750 psi is reached, the handles come out to the OFF



1. Reservoir.
2. Quick-disconnects.
3. Engine pump.
4. Filter.
5. Relief valve.
6. Unloader.
7. Accumulator.
8. Relief manifold.
9. Hand pump.
10. Snubber.
11. Pressure gage.
12. Hand-pump selector valve.
13. Gun-charger valves.
14. Gun-charger cylinders.
15. Control heads (shuttle valve).
16. Landing-gear actuating cylinders.
17. Air bottle.
18. Filler connection.
19. Gage.
20. Vent and vent valve.
21. Dump valve.
22. Wing flap actuating cylinders (outboard).
23. Center section wing flap actuating cylinders.
24. Restrictors.
25. Wing folding timer check valves.
26. Wing lock cylinder.
27. Oil-cooler actuating cylinder.
28. Restrictors.
29. Upper cowl flap actuating cylinders.
30. Lower cowl flap actuating cylinders.
31. Tail-wheel actuating cylinder.

Figure 66.—Diagram of the Hellcat's hydraulic system.

position. This automatically stops the flow from the pump and locks the 750 psi in the gun-charging struts, keeping the guns charged and in the SAFE position.

The thermal pressure-relief line runs from the gun-charging strut line to the Kenyon check-relief manifold where a thermal relief valve set at 1,750 psi relieves excessive pressures into the return line. There are two of these lines—one for the right and the other for the left wing gun.

When the valve is in the FIRE position, the pressure is no longer locked in the struts and the fluid goes out to the return line as soon as a pressure of 750 psi is reached.

COWL FLAPS—

The cowl flap selector valve is located slightly forward and to the pilot's left in the cockpit. It is an Adel poppet-type valve and gets its fluid pressure directly from the general line. The fluid continues through Purolator restrictors to the three actuating cylinders. Two of these cylinders operate the upper cowl flaps and the other operates the lower flaps. The return from the cowl flap selector valve goes into the common return line, then back to the reservoir.

OIL COOLER AND INTERCOOLER SHUTTERS—

The selector valve for the oil cooler and intercooler shutters is located beside the cowl flap selector valve on the left cockpit shelf. Connected in parallel, the shutters need only one selector valve. By placing the selector-valve handle in the OPEN or CLOSED position, fluid pressure is brought from the general line to the intercooler actuating cylinder, which is located aft of the intercooler shutter on the belly of the airplane. At the same time, pressure is built up in the oil-cooler actuating cylinder which is located on the main spar, forward of the fire wall.

Mechanical linkage allows for opening both oil-

cooler shutters which are located aft of the oil-cooler radiators.

WING LOCK—

The wings of the Hellcat fold with the leading edge down, aft in a line parallel to the line of thrust of the plane with the wing tips near the horizontal stabilizer. The wings do not fold hydraulically and therefore must not be allowed to drop and swing when they are unlocked.

The fluid flows from the general line to the selector valve and then to the wing lock cylinders (one on each wing) thereby unlocking the wings. To lock the wings, the selector valve is put in the WING LOCK position and fluid flows to a wing fold timing valve which will not allow the fluid pressure to flow to the lock unless the wing is fully spread.

When the wing is fully spread, the folding panel strikes the timing valve, allowing the fluid to go through and move the lock into the locked position. There is a mechanical lock which must be released before the hydraulic lock is unlocked. This is controlled by a spring-loaded toggle located opposite the landing-gear emergency lever on the panel. The return from the wing lock selector valve goes directly into the top of the Kenyon manifold and into the return line.

WING FLAPS—

To lower the flaps when the engine is running, throw the flap toggle switch located on the left-hand cockpit shelf to the DOWN position. This, in turn, energizes a Servo motor which moves the hydraulic selector valve to the DOWN position.

The fluid under pressure comes from the wing flap line through the selector valve to the actuating cylinders by way of Purolator restrictors. As the inboard and outboard flaps are not mechanically connected, these restrictors (1 on each working

line, 8 in all) insure a simultaneous movement of the flaps.

These flaps lower 48° and, at the same time, extend 6 inches rearward with a minimum of 15° when they are in the down position. A torque-tube shaft with integral lever arms, connecting links, control rods, bellcranks and compression spring units moves the flaps up and down. This compression spring unit automatically controls the degree of droop according to the air speed.

The spring is designed so that its tension is in direct proportion to the aerodynamic load imposed on the flaps at various air speeds. The air load on the flaps at 95 knots air speed starts raising them and at 150 knots air speed they will have raised to their minimum of 15° droop. At 170 knots air speed, they will automatically retract to their full up position.

This is accomplished by a speed switch located on the leading edge of the wing center section on the right-hand side. This switch is connected in parallel with the airplane's air speed pitot-tube lines. At 170 knots air speed, its breaker points make contact and close the electric circuit which energizes the electric Servo motor located above the flap manual-control lever on the lower left-hand side of the cockpit. The motion of this motor operates the flap selector valve, thereby energizing the flap hydraulic system. If the flap control switch is left in the DOWN position, the flaps will automatically lower when the air speed drops below 170 knots.

In case of failure of the engine pump or the electrical system, put the flap manual-control lever, which is on the lower left-hand side of the cockpit, to the desired flap position—put the hand pump selector valve to the wing flaps position—and operate the hand pump approximately 35 cycles to extend and 25 cycles to retract the flaps.

For retraction of the landing gear, the landing-gear selector valve (located below the instrument panel) is placed in the UP position. Fluid pressure goes from the landing-gear line through the selector valve to the landing gear and tail-wheel actuating cylinders. The landing-gear cylinder moves back about 3/4 of an inch. This movement, through mechanical linkage, unlocks the horse-shoe down lock. The piston is then free to move. As the piston moves forward, the landing gear retracts, turning 87° on sector gears, and lies flat in the wheel well. It is held up by an UP lock in the form of a J-hook which goes around the oleo strut.

In extending the landing gear, the selector valve is moved to the DOWN POSITION. Fluid pressure goes through the selector valve to the piston end of the actuating cylinder. The cylinder moves back to its original position. This movement unlocks the J-hooks, allowing the gear to drop down to the landing position and the horseshoe locks it in place.

EMERGENCY OPERATION.

In the event of hydraulic system failure, the Hellcat's landing gear cannot be dropped by its own weight because it will fall directly into the slip stream. For this reason, nitrogen is employed to lower the gear when the operation cannot be done hydraulically.

A landing-gear emergency release handle, located on a panel beneath the instrument panel, is moved to the DOWN position. This does four things.

First, it closes a vent valve located under the pilot's left foot trough to allow any leakage from the shuttle valve to go overboard.

Second, it opens a dump valve to the return line. This valve allows the return fluid to bypass the selector valve when the gear is forced down. (The

dump valve is located in the same spot as the vent valve.)

Third, it releases the tail-wheel UP lock, allowing a spring to force the gear down.

Fourth, it releases nitrogen stored at 1,800 psi in a bottle on the bulkhead directly behind the pilot's seat. This nitrogen goes into the lines and up to the shuttle valves. These valves then close off the normal fluid entry port, keeping the nitrogen from entering the system. From here, the nitrogen goes directly into the main-gear actuating cylinder, lowering the gear and locking it in place.

To release the nitrogen after landing, the landing-gear emergency release is pulled to the UP position which closes the dump valve and opens the vent valve, allowing the nitrogen to escape overboard.

CHAPTER 11

TROUBLE SHOOTING

SAME OLD STORY

The chief cause for worry in an aircraft hydraulic system is the same "Old Man Trouble" that plagues the men who sail the Seven Seas—the development of LEAKS.

In fact, springing a leak in an aircraft hydraulic system is even more serious than springing one in the hull of a ship. A leak in the hull of a sea-going vessel can be patched temporarily and the vessel brought to a shipyard for permanent repairs. A leak in the hydraulic system, developing while the aircraft is in the air, is a lot more serious. It may mean that pressure will be lost to the extent that the landing gear cannot be extended, landing flaps cannot be lowered, guns cannot be charged, and wheel brakes cannot be applied. THAT'S BAD.

The boys in the air rely on YOU to see that the hydraulic system is in the best possible order BEFORE they take to the air.

The selection of proper tubing for any hydraulic system is based on the maximum required fluid flow and the maximum working pressure of the system. MAXIMUM REQUIRED FLOW determines the tubing size. MAXIMUM SYSTEM PRESSURE determines the material and wall thickness used.

Recent Army-Navy specifications require that hydraulic system tubing be able to withstand a pressure at least 5 times that of the normal operating pressure of the system.

Most hydraulic system tubing connections are made with flared-tube couplings. The efficiency of a joint of this type depends on the correct clamping of the tubing between the two sections of the fitting.

To prevent leaks at the joint, the flare must be of the correct size and the pressure exerted by the clamping nut must be uniform over the entire flared area. Three types of common errors in making tubing flares are shown in figure 67.

In the drawing at the left, the tubing flare is too short. When this happens, the full clamping area of the fitting is not utilized and—because of the small area of tubing that is clamped—the flare is apt to be squeezed thin. A TOO-SHORT flare will break or pull out under strain. It is almost impossible to make a leaktight joint when this condition exists.

When the tubing flare is TOO LONG (center drawing), the flare will jam on the threads of the coupling nut during assembly, and is likely to seat against the bottom of the coupling nut rather than on the tapered seat of the coupling. Leaks are sure to develop if the flare is too long.

Uneven flares, as shown in the third drawing, are caused by not cutting the tubing end square. These flares cannot be alined with the seating sur-

face of the fitting and, again, a leaktight joint is almost impossible.

HERE'S THE RIGHT WAY TO DO IT!

Cut the tubing straight and square, remove all

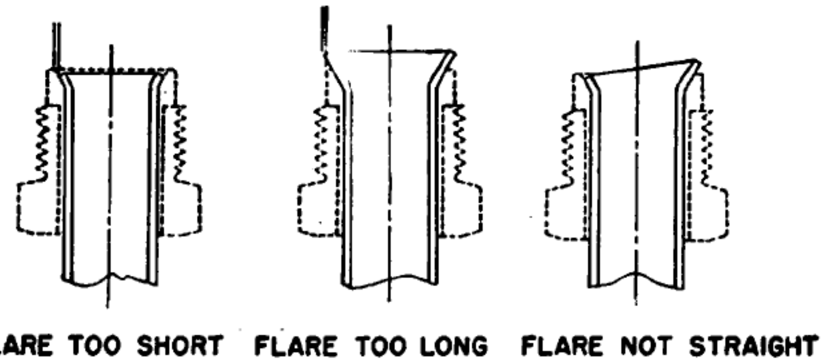


Figure 67.—How NOT TO make tubing flares.

burrs and scratches. Make sure that the tubing cross-section is perfectly round.

Use the correct flaring tool for the type of fitting used. Flaring tools are designed to produce the correct flare angle for ONE TYPE OF FITTING ONLY.

Flare the tubing fully and to the correct angle so that it will fit the contour of the fitting sleeve. This is shown in figure 68.

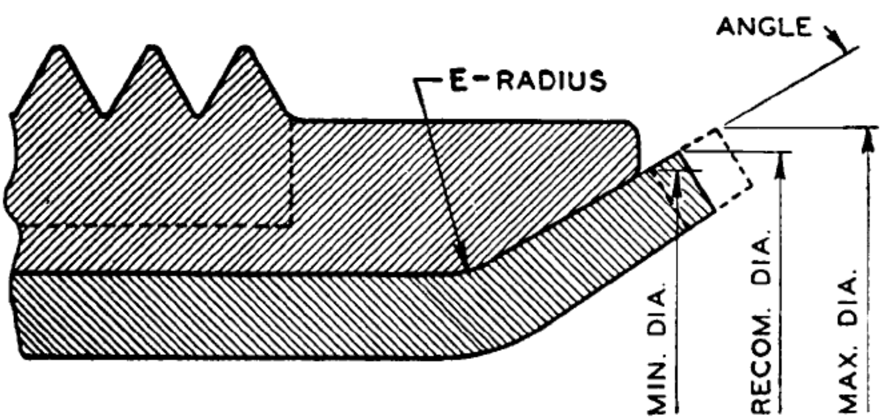


Figure 68.—The correct flaring angle.

There's no royal family in hydraulic tubing. Bends must be uniform (without Kinks) and the radius of the bends should follow Army-Navy specifications. Aluminum-alloy tubing of small outside

diameter can be bent successfully by the use of wound spring-type benders or hand benders. For the correct bending of thin wall aluminum alloy tubing of larger sizes and corrosion-resisting steel tubing, it is necessary to use a tubing bender incorporating a mandrel which prevents collapse of the tubing at the bend.

Tubing replacements in hydraulic system lines should be made with tubing the same size, material and wall thickness as the tubing removed. In emergencies, other tubing can be substituted but replacement with the correct tubing should be made at the first opportunity.

Aluminum-alloy parts, particularly threaded parts, must be HANDLED WITH CARE. Valves and similar parts can be damaged beyond repair through inexperienced and careless handling.

The trouble most frequently encountered is MECHANICAL ABUSE such as excessive wrench pressure in the make-up of joints, distortion of parts when held in vises, and other similar conditions. Be careful when assembling aluminum-alloy tubing fittings and these abuses will not occur.

Aluminum alloy has the tendency to seize or gall when two threaded parts are screwed together. This is particularly serious on pipe thread connections and where cast alloys are used. In service, the seizure of threads of tubing fittings can be reduced to a minimum by the use of anti-seize compounds or thread lubricants.

Self-sealing couplings, sometimes called QUICK-DISCONNECT FITTINGS, are used where fluid lines must be disconnected for servicing or testing. Self-sealing couplings make it possible to separate and reconnect hydraulic lines without loss of fluid or getting air in the system.

By referring to figure 69 you can see that a self-sealing coupling is connected or disconnected by simply screwing or unscrewing a union nut. This

illustration shows the valve, in cross-section, in three stages of connection and disconnection.

One half of the coupling consists of a body into which an end adapter is screwed. Inside the body

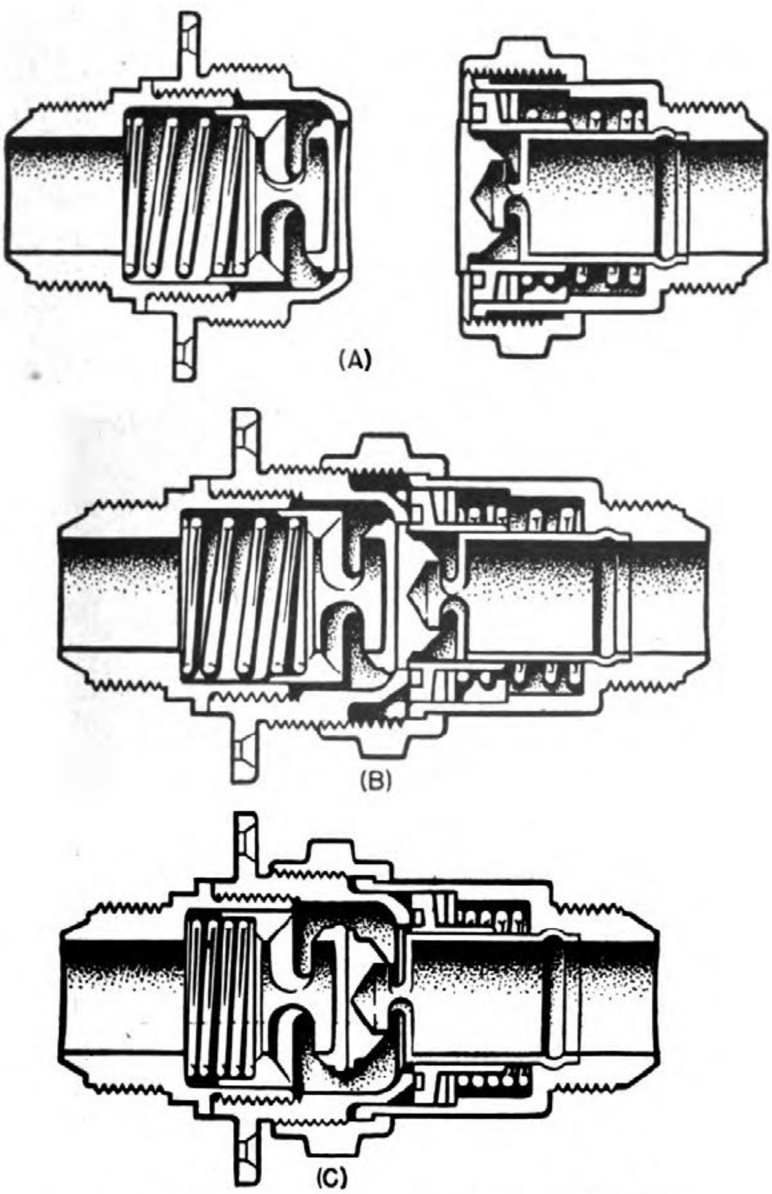


Figure 69.—Connecting a self-sealing coupling.

is a valve that is held against its seat by the pressure of a spring assisted by the pressure of the fluid in the tubing line.

The other half consists of a body with a fixed

tubular valve and a sleeve sliding on the outside diameter of the tubular valve. The sleeve is held against the seat of the tubular valve by the spring. This spring also serves the purpose of holding a metal washer against a packing ring, thus providing a seal.

When the two halves of the coupling are connected by screwing the union nut on the threads of the flanged body, the seating portions of the body make contact with the seal in the sleeve. Further tightening of the union nut causes the sleeve to be moved away from the opening in the tubular valve. At the same time, the valve in the flanged body is forced from its seat by the tubular valve in the other body. In this condition, free fluid flow through the fittings is permitted.

SWIVEL JOINTS are used in aircraft hydraulic circuits when it is necessary to conduct fluid from a stationary to a movable object. They are constructed so that the fluid will not leak despite rotation of the movable object through any angular distance.

In general, fluid swivel joints include three principal parts. These are the housing, a spindle, and a packing group which permits relative motion of the spindle and the housing.

In the swivel joint, the housing is comprised of a cylindrical aluminum-alloy body fitted with two threaded bosses for the connection of fluid lines. One end of the housing is closed by an integral head, while the opposite end is open and threaded to receive the packing group.

The packing group includes packings, spacers, glands, and rings. It provides two sealed circumferential channels extending completely around the inner surface of the housing body. The fluid connection bosses register with these fluid channels. The spindle assembly passes through the center of the packing group and is located within the

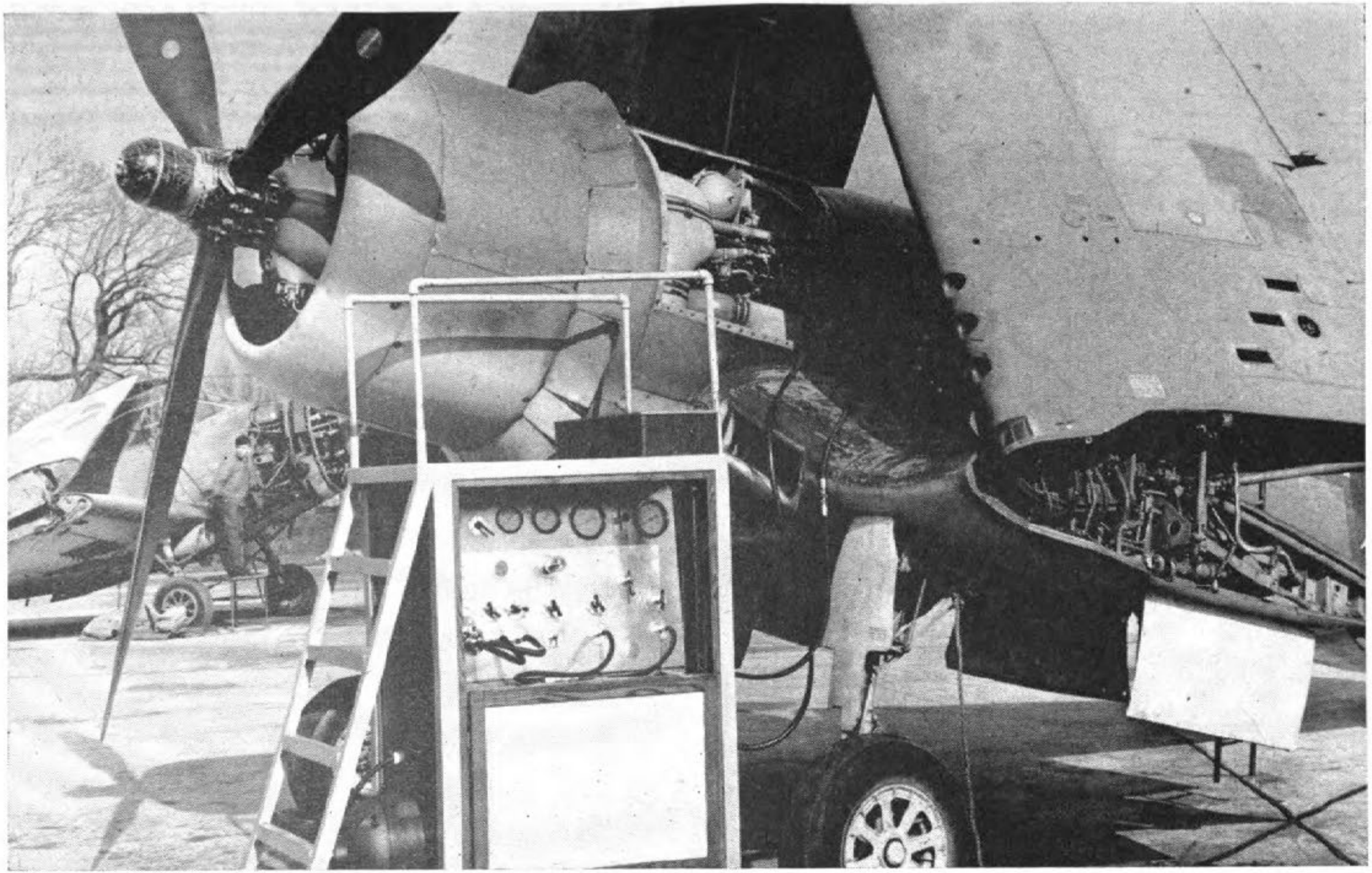


Figure 70.—Test stand.

housing by the packing retainer cap. It bears against a special split washer that, in turn, bears against an integral shoulder on the spindle.

The spindle is formed by an assembly of two concentric tubes that have threaded connections for fluid lines at their outer ends. Ports in the tubes register with the channels in the packing group.

Thus the combination of housing, packing group and spindle makes possible the transmission of fluid between these parts.

SYSTEM MAINTENANCE

Careful maintenance pays BIG DIVIDENDS! Hydraulic mechanisms are precision units. Smooth operation depends on proper care. The smallest particle of dirt can interfere with the functioning of important valves, and can disable an entire system. Many hours will be saved and many planes will be kept in operation if you remember that CLEANLINESS is of paramount importance.

As an efficient mechanic, you must have a clear understanding of what takes place when the hydraulic system functions normally. Study the schematic drawing of a system until you are thoroughly familiar with the principles of operation and with the relationship of the various units. Don't count on LUCK, or the blundering approach. Such a maintenance procedure results in further complication of the difficulty.

The logical methods of diagnosing or of remedying trouble are quite simple. Generally you will begin with certain questions. Is there fluid? Is there pressure? Has the selector valve been placed in the proper position? There are actually very few things that can go wrong with a system that has at one time functioned properly. Improper operation can generally be traced to one of the following causes.

INSUFFICIENT FLUID IN THE SYSTEM.

USE OF WRONG TYPE OF FLUID.

AIR IN THE SYSTEM.

MECHANICAL DAMAGE OR STRUCTURAL FAILURE.

ITERNAL OR EXTERNAL LEAKAGE.

DIRT IN THE SYSTEM.

IMPROPER ADJUSTMENTS.

If the trouble is not readily disclosed, the cause of failure may be located by following a process of elimination. A careful analysis of the relationship between the units and the trouble will indicate that certain of the units could not possibly be involved.

The power system supplies fluid under pressure to the various unit systems. Therefore, when failure occurs, the power system should be checked first. Unit systems can be isolated by placing their respective selector valves in neutral position.

The following procedure is suggested for trouble-shooting the power system—

1. Check the reservoir for proper amount of fluid.
2. Check suction or supply line to engine pump for leakage, for dents, and for loose connections.
3. Check output of engine pump by turning the propeller several times either by hand or by engine operation.
4. Check the disconnect fittings at the firewall for tightness.
5. Check operation of the pressure regulator for proper cut-in and cut-out by using a test stand or an engine pump. (If a time-delay or power control valve is used, operate by depressing the plunger. Operating time should conform with specifications in the Erection and Maintenance Manual.)
6. Check the relief valve when possible by using the hand pump. Operation of the hand pump is also checked at this time.
7. Check accumulator for leaks. Check the air preload in the accumulator. One type check can easily be made with the main system pressure gage by proceeding as follows—
   a. Place all selector valves in "neutral" position.

b. Place the hand pump control valve in such a position that the hand pump pressure will go into the accumulator. (By-pass check valve in "ground" position on F4U–1. Hand pump selector valve in "system" position on F6F. The TBF accumulator preload pressure cannot be checked by this method.)

c. Pump the hand pump two or three strokes.

d. The gage will immediately jump to the pre-load setting of the accumulator. The pressure recorded on the gage just as it stops rising fast, indicates the pre-load pressure in the accumulator.

An alternate method of checking the accumulator pre-load pressure is as follows—

a. Build up system pressure in the accumulator by using either the hand pump or the engine-driven pump, depending upon the design of the system.

b. Make sure that the gage records the pressure in the accumulator. (F6F—hand pump selector valve in "system" position. TBF—hand pump selector valve in "general" position.)

c. Bleed the system pressure off slowly (no pumps should be operating) by actuating some small unit such as the cowl flaps.

d. The pressure recorded by the gage just before it drops abruptly to zero indicates the air pre-load pressure in the accumulator.

If the pre-load is found to be incorrect, the accumulator should be charged to the specified pre-load.

Following are charts indicating troubles which may occur in aircraft hydraulic systems, the possible causes of failure, and suggested remedies.

THE POWER SYSTEM

Trouble	Possible Cause	Remedy
1. Failure of the engine pump to deliver flow.	1. Low fluid level in reservoir.	1. Fill reservoir to proper level, using the specified fluid.
	2. Pressure and supply lines reversed.	2. Trace lines and connect correctly.
	3. Pump drive shaft sheared.	3. Replace drive shaft.
	4. Pump cover reversed.	4. Reverse cover.

Trouble	Possible Cause	Remedy
2. Pressure regulator cuts in and out too frequently.	1. Accumulator air preload too high.	1. Reduce to correct pressure.
	2. Low or no accumulator preload.	2. Change to correct pressure. Keep hydraulic system gauge at zero by operating any one of the selector valves. Never charge accumulator against fluid pressure — incorrect preload will result.
	3. Loss of air preload in accumulator.	3. Check air valves and fittings for leakage. A leaky diaphragm will allow fluid to enter the air chamber—a new diaphragm must be installed.
	4. Leaks in the system. *a.* Internal.	4. *a.* Internal leakage may be located by checking with hand pump. Correct leakage when located.
	b. External.	*b.* Visual inspection of the system will readily disclose external leaks. Correct leakage when located.
	5. Excessive restrictions in the line.	5. Adjust correctly. If the cause is due to dirt, remove unit or line and clean.

TROUBLE	POSSIBLE CAUSE	REMEDY
3. Loss of system pressure.	1. Low fluid level in reservoir. 2. Excessive leakage, internal or external. *a.* Regulator stuck in the cut-out position. *b.* Relief valve unseated by foreign particle. *c.* Leakage at poppets in selector valves. d. Engine pump failure. *e.* Leaky check valve in pressure regulator.	1. Refill to proper level. 2. *a, b, c,*—Tap the unit with a mallet. Several cycles of operation should follow, to wash obstruction clear. If trouble still persists, remove unit. Check it on test stand. If necessary, repair or replace the unit. *d.* Refer to pump failures. *e.* Repair or replace.
4. Handpump fails to deliver flow.	1. No fluid reservoir. 2. Leaky suction check valve in hand pump. 3. Suction line to hand pump clogged. 4. Leaky seals on piston in hand pump.	1. Fill reservoir to proper level. 2. Clean or install a new check valve. 3. Disconnect line and clean. 4. Replace.

If the foregoing tests show that the power system is operating normally, it can now be eliminated from the diagnosis.

The following charts show possible causes of failure in the unit systems.

TROUBLE	POSSIBLE CAUSE	REMEDY
1. Failure of landing gear to retract.	1. Lines crossed.	1. Trace lines and connect correctly.
	2. Selector valve bypassing fluid to return (sticking poppet).	2. Repair or change selector valve.
	3. Excessive back pressure created by restrictions due to kinks, or excessive bends.	3. Trace lines—move obstruction — replace tubing.
	4. Leaky shuttle valve creating back pressure. This forces the ball against seat of normal fluid entry port.	4. Clean or replace shuttle valve.
	5. Internal leakage.	5. Check schematic for sources of possible leakage—bypass valves, dump valves, and crossover valves.
	a. Excessive leakage past the seals in the actuating cylinder.	*a.* Replace seals in cylinder.
	b. Leakage past seals in downlock cylinder.	*b.* Replace seals in downlock.
	6. Faulty mechanical linkage.	6. Repair, or replace if necessary.

Trouble	Possible Cause	Remedy
2. Sluggish operation of landing gear.	1. Internal leakage at seals in actuating cylinder.	1. Replace seals or cylinder.
	2. Selector valve poppets by-passing fluid.	2. Repair selector valve.
	3. External leakage.	3. Tighten fittings or replace tubing if necessary.
	4. Excessive restriction caused by damaged tubing, kinks, or sharp bends.	4. Replace tubing.
	5. Selector valve handle improperly adjusted or restrictions caused by maladjustment of units, such as restrictors.	5. Adjust unit to proper operation or replace if necessary.
3. Jerky operation during retraction.	1. Air in the system.	1. Trace source of entry—then remedy. Remove air by operating landing gear through several cycles.
	2. Insufficient fluid.	2. Replenish fluid in system.
	3. Excessive binding of packings and seals.	3. Loosen packing unit and adjust properly.
	4. Resistance due to mechanical linkage.	4. Inspect and lubricate if necessary.

Trouble	Possible Cause	Remedy
4. Failure of landing gear to extend normally.	1. Maladjustment of units, such as sequence valves, etc.	1. Adjust properly and check operation with hand pump.
	2. Leakage past seals in uplock cylinder.	2. Replace seals.
	3. No system pressure. On the majority of planes if normal extension fails, an emergency means is provided for dropping the gear. Should this fail, the trouble can be traced to excessive binding or misalignment of the mechanical linkage.	3. Refer to power system data.

WING FLAP SYSTEM

Trouble	Possible Cause	Remedy
1. Wing flap operating too slowly.	1. Dirt in restrictor or relief valve.	1. Remove and clean restrictor or relief valve.
	2. Fluid being bypassed by leaky seals in cylinder.	2. Replace seals.
	3. Poppet leakage in selector valve.	3. Repair or replace.
	4. Selector valve not fully open due to maladjustment of selector valve handle.	4. Adjust or replace unit.

Trouble	Possible Cause	Remedy
2. Wing flaps fail to extend.	1. Fluid loss caused by sticking relief valve.	1. Remove and clean relief valve. Replace if necessary.
	2. Faulty adjustment of relief or by-pass valves.	2. Inspect and adjust to specified setting.
	3. Working lines crossed.	3. Trace lines and connect correctly.
	4. Flow stopped at restrictor. Dirt present.	4. Remove and clean. (Flush system)
3. One wing flap comes down before the other.	1. Mechanical interference — binding of linkage.	1. Rework flaps until free movement is noticed.
	2. Flow stopped by dirty lines.	2. Clean the lines.
	3. Flow equalizer, if used, not functioning properly.	3. Repair or replace.
4. Jerky operation of flaps.	1. Air in the system.	1. Bleed system by operating through several cycles.
	2. Excessive drag caused by linkage creates chattering effect.	2. Rework until free movement is obtained.
	3. Binding of packings and seals.	3. Loosen packing nut and adjust properly.

WING FOLD SYSTEM

Trouble	Possible Cause	Remedy
1. Wings will not unlock.	1. Manual lock jammed in wing-lock cylinder shaft.	1. Release or rework manual lock.
	2. Fluid by-passing piston seals in wing-lock cylinder.	2. Change seals on piston or replace cylinder.
	3. Fluid by-passing selector valve.	3. Repair or replace selector valve.

TROUBLE	POSSIBLE CAUSE	REMEDY
	4. Binding of wing-lock pins due to leaky sequence valve allowing fluid pressure to act on actuating cylinder first.	4. Check condition of sequence valve and clean. Replace if necessary.
	5. Flow stopped at units such as sequence valves. If a flow equalizer is used, stoppage of fluid flow in one wing will prevent the other wing from unlocking.	5. Check adjustment installation and general condition of valves. Check related units in wing-fold system.
2. Wings will not lock in spread position.	1. Striker screw does not contact sequence valve.	1. Readjust or straighten, if bent.
	2. Misalinement of wing-lock fittings.	2. Realine fittings to specification.
	3. Fluid by-passing through seals of wing-lock cylinders.	3. Change seals or replace cylinder.
	4. Wing fold cylinders out of adjustment.	4. Adjust to give full throw of wings.
3. Wing lock creeps or locks before wing is fully spread.	1. Leaky wing-lock sequence valve admitting fluid pressure.	1. If dirt cannot be washed away, rework or change sequence valve.
	2. Excessive adjustment on striker screw, operating the lock, before wing fittings are in line.	2. Adjust to conform with specifications. Do not exceed them.

TROUBLE	POSSIBLE CAUSE	REMEDY
1. Charging cylinder fails to retract bolt fully or responds very slowly.	1. *a.* System pressure too low.	1. *a.* Check main hydraulic system pressure.
	b. Improper mounting of gun charging cylinder.	*b.* Check mounting of cylinder. Check engagement of cylinder lug with gun bolt pin.
	c. Release valve spring in valve set too low.	*c.* Adjust release valve to specified operating pressure.
	d. Release valve seat leaking.	*d.* Clean, rework, or replace release valve.
	e. Internal leakage from pressure to return with valve in charge position. Caused by excessive clearance between piston and housing due to wear.	*e.* Replace valve.
2. Guns fail to move to arm position.	2. *a.* Release valve spring set too high.	2. *a.* Adjust release valve to operating pressure.
	b. Gun charger in safe position.	*b.* Check position of handle.
	c. Main system pressure too low.	*c.* Check planes system for nominal operating pressure.
	d. Bolt lock does not release.	*d.* Check locking mechanism and correct.
	e. Dirt or grit causing plunger to stick.	*e.* Remove and clean.

TROUBLE	POSSIBLE CAUSE	REMEDY
	f. Piston in gun charging cylinder sticking.	*f*. Remove and check.
3. Slow return of cylinder piston to arm position.	3. *a*. Piston in cylinder sticking.	3. *a*. Remove cylinder and check.
	b. Restriction at cylinder port of valve.	*b*. Clean cylinder port.
	c. Back pressure too high in main system restricting return.	*c*. Check main system return line for restriction.
4. Cylinder line bursts on charging operation.	4. *a*. Plunger (timing pin) releasing too soon, allowing bolt pin in gun to strike cylinder lug.	4. *a*. Check release valve setting; correct to proper operating pressure.
	b. Worn latch lever on cylinder.	*b*. Replace latch lever.
	c. Plunger (timing pin) in actuating cylinder binding, releasing bolt too soon. See trouble No. 3.	*c*. Disassemble and check plunger (timing pin) in cylinder for free movement.
5. Guns failing to hold in safe position.	5. *a*. Cylinder check valve leaking.	5. *a*. Clean and reseat ball.
	b. External leak.	*b*. Trace system and correct.
	c. Outlet check valve pin binding or sticking in open position.	*c*. Remove and clean the check valve.

Trouble	Possible Cause	Remedy
6. Gun charging valve does not snap out fully, causing continuous bleed of main hydraulic system pressure.	6. *a.* Weak plunger return spring.	6. *a.* Replace.
	b. Sticking plunger due to dirt.	*b.* Remove valve. Clean and check.

AIRCRAFT HYDRAULIC BRAKES

The troubles listed pertain to a brake system which derives its source of fluid energy from the ship's hydraulic system. A power brake control valve releases and simultaneously regulates this pressure to the brake at the will of the pilot. The pressure obtained at the brake is proportional to the force applied by the pilot's foot against the brake pedal. Should failure occur, inspect units, such as wheel brakes, lines, and linkage before deciding the brake control valve is at fault.

Trouble	Possible Cause	Remedy
1. Brakes release slowly.	1. *a.* Return port does not open fully in brake valve.	1. *a.* Check clearance between push rod end and lever with brakes fully released.
	b. Back pressure present in return line to reservoir, caused by excessive bends, kinks or improper size of tubing.	*b.* Check condition of tubing; replace if necessary. Install correct size tubing.
	c. Weak or broken return springs at brake.	*c.* Remove wheel and check. Replace if necessary.

TROUBLE	POSSIBLE CAUSE	REMEDY
2. Brakes grab upon sudden application.	2. *a.* Maximum Pressure admitted to brake is too high.	2. *a.* Adjust pressure to correct value by high pressure adjustment.
	b. Grease between braking surfaces.	*b.* Remove and clean with an approved cleaning agent; replace shoe type; clean disk type.
	c. Insufficient clearance between braking surfaces.	*c.* Adjust brake clearance to specification.
3. Low pressure at brakes with full push rod stroke.	3. *a.* Weak or broken regulating spring.	3. *a.* Replace.
	b. Low system pressure.	*b.* Check pressure in main system as indicated by gage. Trouble shoot and correct failure.
	c. High pressure adjustment set too low.	*c.* Readjust properly.
4. Brakes will not hold pressure at a constant level. Brake pressure changes without change of pedal pressure.	4. *a.* Internal leakage at power brake valve.	4. *a.* Remove valve, inspect seals and lapped surfaces. Repair or replace.
	b. External leakage in brake system.	*b.* Trace lines to brake cylinder. Check the condition of tubing and connections. Tighten, reflare, or replace faulty tubing.

Possible troubles, causes, and remedies in a brake system using a master cylinder as a means of control.

TROUBLE	POSSIBLE CAUSE	REMEDY
1. Insufficient brake action.	1. *a.* Excessive clearance between braking surfaces due to worn surfaces or maladjustment.	1. *a.* Adjust to proper clearance. Replace if worn excessively.
	b. Air in the system.	*b.* Bleed brake system, being careful to remove all air from lines or same trouble will persist.
	c. Lack of fluid in supply system.	*c.* Replenish supply system. Check system for leaks. Bleed system.
	d. Internal leakage in master cylinder caused by bad piston seals, or scores on cylinder wall.	*d.* Replace seals. Recommend honing of small scores. Replace cylinder if scores are too pronounced.
	e. Vent line in reservoir clogged.	*e.* Check supply system. Remove obstruction.
2. Dragging brakes.	2. *a.* Insufficient clearance of braking surfaces.	2. *a.* Check clearance.
	b. Dirt in the system.	*b.* Flush system with an approved solution or specified fluid.

Trouble	Possible Cause	Remedy
	c. Use of improper fluid.	*c.* Flush system thoroughly with the proper cleaning agent. Replace all seals, fill and rebleed.
	d. Fatigued or broken brake return spring.	*d.* Replace.
	e. Binding of pedal linkage.	*e.* Check installation and free movement of linkage.
	f. Compensating port in master cylinder clogged.	*f.* Flush system if trouble persists. Remove master cylinder and clean.
3. Grabbing brakes.	3. *a.* Insufficient clearance of braking surfaces.	3. *a.* Check clearance.
	b. Lubricant on braking surfaces.	*b.* Recommend replacement of braking surfaces on shoe type brakes. Remove lubricant on disk brakes with an approved cleaning solvent.

PRE-FLIGHT INSPECTION

(Prior to the first flight of day)

1. Check the fluid level in the reservoir.
2. Operate some unit with the hand pump as a means of checking hand-pump operation.
3. Check accumulator preload according to instructions.
4. Start the engine and test all units which may be operated on the ground.

5. Place selector valves in neutral and check the cutting-in and the cutting-out of the pressure regulator. Observe readings on pressure gage.
6. Check operation of brakes by taxiing the plane.
7. Turn filter handle a few times.
8. Check fluid level in reservoir. Air in the system is expelled through the reservoir vent during operation. As the air escapes, the fluid level in the reservoir will drop. Consequently, the level should again be checked at the conclusion of the inspection.

THIRTY-HOUR INSPECTION

This more complete check is performed after 30 flight hours.

1. Support the airplane off the ground.
2. Disconnect the main pressure and the main return lines at fire-wall, and connect the corresponding lines from test stand.
3. Check landing gear retraction and extension, as well as other unit systems. Use the hand pump first, then the test stand.
4. Check condition and security of all system units.
5. Check condition of tubing, fittings, flexible hose, mounting brackets, clamps, and bonding.
6. Check the mechanisms related to hydraulic units, both at rest and during operation.
7. Service mechanisms requiring lubrication at this time.

TEST STANDS

Thorough inspections and maintenance necessitate an auxiliary source of power. A test stand of the type pictured in figure 70 can be constructed at little or no cost by using spare units and salvaged materials. Time spent in its construction will be repaid by the labor saved in locating and in eliminating system difficulties. In addition, the valuable saving of time is evident when you consider that inspections with the test stand can be pulled without the engine in the plane.

Figure 70 shows the manner in which the test stand should be connected to a plane. Checks can be performed with the test stand if power is available to drive a 10 hp motor. All necessary tools are included in the built-in tool chest on the top of the stand. All stand units are accessible through removable panels.

How Well Do You Know—

AIRCRAFT HYDRAULIC EQUIPMENT

QUIZ

CHAPTER 1
HOW IT WORKS

1. What 6 advantages of hydraulic equipment make it preferable over electricity or compressed air for actuating aircraft mechanisms?
2. The principles of hydraulic action are based on an inherent characteristic of all liquids. What is that characteristic?
3. What is the difference between "pressure" and "force"?
4. (*a*) What is the normal loss of power in operating hydraulic units of an airplane?
   (*b*) What causes this loss?
5. (*a*) Why are hydraulic fluids colored differently?
   (*b*) What color are fluids having mineral oil base?
6. What type of packing used in aircraft hydraulic systems works better in one direction than in the other? What is another name for this type of packing?

CHAPTER 2
PRIMARY UNITS

1. Why does the power pump line or standpipe always enter the reservoir considerably above the bottom of the tank?
2. What does "double-acting" mean, in reference to a hand pump?
3. (*a*) What two general types of power pumps are used on aircraft hydraulic systems?
   (*b*) Which is the more powerful?
4. (*a*) By what device is fluid directed through the system to the place where it is to be used?
   (*b*) What are the four types of this device?
5. (*a*) What are the two kinds of actuating mechanisms used in aircraft hydraulic systems?
   (*b*) Which one must be used when rotary motion is desired?

CHAPTER 3
SECONDARY UNITS

1. What hydraulic unit performs the function of a relief valve, on a much broader scale?

2. (*a*) A pressure accumulator in a hydraulic system serves the same purpose as a unit commonly found in electrical systems of aircraft as well as automobiles. What is that unit?
   (*b*) What two substances are normally contained in an accumulator?
3. (*a*) What two types of filters are used in aircraft hydraulic systems?
   (*b*) How is each cleaned?
4. (*a*) Where in the system are filters usually installed?
   (*b*) Where must they never be installed?

CHAPTER 4

SPECIAL VALVES

1. (*a*) What is the purpose of using orifice check valves in hydraulic lines?
   (*b*) In what two hydraulically operated aircraft mechanisms is the orifice check valve particularly useful?
2. (*a*) What is the fundamental difference between the functions of the relief valve and the power-control valve?
   (*b*) Power-control valves are used only in hydraulic systems which do not have what other unit?
3. What device makes it possible to lower an airplane's wheels when the hydraulic actuating system has failed?
4. Why does this make it necessary to include a flow equalizer in the wing flap system?
5. What are the hydraulic symbols for—
   (*a*) Pressure supply line?
   (*b*) Return line?
   (*c*) Pressure accumulator?
   (*d*) Relief valve?
   (*e*) Actuating cylinder?

CHAPTER 5

BRAKES AND STRUTS

1. (*a*) How many distinct types of hydraulic brakes are used on aircraft?
   (*b*) Which type is generally used on multi-engined and large single-engine aircraft? Why?

2. (*a*) What is the fundamental difference in function between single-servo and duo-servo brakes?
   (*b*) What basic difference in their construction accounts for this difference in function?
3. Which part of the single-servo brake shoe expands first?
4. (*a*) What characteristic of an expander-tube brake determines how many blocks it will have around its circumference?
   (*b*) How are the brake locks prevented from dragging?
   (*c*) How are they prevented from "grabbing"?
5. In the multiple-disk brake—
   (*a*) How are the disks named?
   (*b*) Upon what characteristic of the brake unit does the amount of braking action for any one pressure depend?
6. (*a*) How many chambers does the oleo pneumatic shock absorber strut contain?
   (*b*) What is in each chamber?

CHAPTER 6

HYDRAULIC TURRETS

1. "Decode" these turret code designations:
   (*a*) Martin 250 CH–3.
   (*b*) ERO 250 TH–2.
2. (*a*) How is one general type of turret mechanically different from another?
   (*b*) How is one general type hydraulically different from another?
3. In pump-controlled turrets, how are movements of the gun in azimuth or elevation achieved?
4. What is the function of the relief valve located below the left trunnion in the Martin 250 SH–2 turret?
5. What two outstanding features of the 250 CH Consolidated Tail Turret distinguish it from the other turrets discussed in this chapter?

CHAPTER 7

THE F4U–1 CORSAIR

1. In the Corsair's hydraulic system—
   (*a*) Where is the reservoir installed?
   (*b*) What lines connect into the reservoir?

2. In what position should the airplane be when hydraulic fluid level is measured?
3. What serves as a junction box for the hydraulic lines? Where is it located?
4. What six systems of the Corsair are operated by hydraulics?
5. Which system includes the dive brake?
6. Which system includes a howler?

CHAPTER 8
THE SBD DAUNTLESS

1. What is the operating pressure for the Dauntless' hydraulic system?
2. What units of this airplane are operated by hydraulics?
3. What units are hydraulically operated by "a cylinder within a cylinder"?
4. What is the distinguishing difference between the Dauntless' and other hydraulic systems?

CHAPTER 9
THE TBF–1 AVENGER

1. (*a*) Which of the hydraulically operated units of this airplane are not operated from the main hydraulic system?
   (*b*) How many of the airplane's major units are (directly or indirectly) hydraulically operated?
2. What is the operating pressure for this hydraulic system?
3. How many individual lines are used to distribute the fluid under pressure, after it passes through the power system and main pressure line?
4. What two units on this airplane are usually operated together?

CHAPTER 10
THE F6F–3 HELLCAT

1. What units on the Hellcat are operated by hydraulics?
2. What is the system operating pressure?
3. What are the four pressure lines from the Kenyon check relief manifold?
4. (*a*) Why isn't it practical to allow the Hellcat's landing gear to drop by its own weight, in the event of hydraulic system failure?
   (*b*) What is employed to lower the gear in such an emergency?

ANSWERS TO QUIZ

CHAPTER 1

HOW IT WORKS

1. Light weight.
   Simple maintenance.
   Economy.
   Adaptability to heavy load conditions.
   Instant response for starting or stopping.
   Compactness.
2. They are incompressible.
3. PRESSURE refers to the load applied to each square inch of area, whereas FORCE is used to designate the total load that is applied to the total area.
4. (*a*) 10 to 20 percent.
   (*b*) Friction.
   Mechanical resistance of the moving parts.
5. (*a*) As an aid in distinguishing between them, because they are not interchangeable in use.
   (*b*) Red.
6. V-shaped. Chevron.

CHAPTER 2

PRIMARY UNITS

1. To make it impossible for the power pump to use up all the fluid in the reservoir and leave none for emergency hand pump operation.
2. Capable of discharging fluid during both up and down strokes of the handle.
3. (*a*) Piston pump.
   Gear pump.
   (*b*) Piston pump. (Multi-piston pump.)
4. (*a*) Selector valves.
   (*b*) Rotor, piston, poppet, ball.
5. (*a*) Actuating cylinder.
   Hydraulic motor.
   (*b*) Hydraulic motor.

CHAPTER 3
SECONDARY UNITS

1. Pressure regulator.
2. (*a*) Storage battery.
   (*b*) Air.
   Fluid.
3. (*a*) Mesh-type.
   Edge-type.
   (*b*) Mesh-type: Rotating a scraper by the handle at top.
   Edge-type: Rotating the disks with the handle.
4. (*a*) On the system return line. (On pressure lines, if necessary.)
   (*b*) Pump suction lines.

CHAPTER 4
SPECIAL VALVES

1. (*a*) To restrict the flow of fluid in one direction only, allowing a free flow the opposite way.
   (*b*) Wing-flap system.
   Landing-gear system.
2. (*a*) The power-control valve permits the circulation of fluid from power pump to reservoir without making it necessary for the pump to maintain such high pressures as are needed to keep a relief valve open.
   (*b*) Pressure accumulator.
3. Emergency unloading valve.
4. If there were no control over the division of fluid flow to the two cylinders, any difference in resistance to movement would cause the flap having the least resistance to be lowered first.
5. Check your answers against figure 39.

CHAPTER 5
BRAKES AND STRUTS

1. (*a*) Three.
   (*b*) Multiple-disk brakes. Because this type provides a greater braking surface than the other types.
2. (*a*) Single-servo brake action is effective for one direction of wheel rotation only, whereas duo-servo brakes are effective for either direction.

(*b*) The single-servo brake actuating cylinder has only one piston, whereas the duo-servo cylinder has two pistons.

3. The primary shoe.
4. (*a*) The diameter of the brake.
   (*b*) By flat springs fitted into slots in both the blocks and frame so as to hold the blocks against the expander tube when the brake is released.
   (*c*) By being constructed so that each block is independent in its action and servo-action is not built up.
5. (*a*) According to whether they can or cannot rotate with the wheel the disks are named rotor and stationary, respectively.
   (*b*) The amount of braking surface.
6. (*a*) Two.
   (*b*) Upper chamber: Air.
   Lower chamber: Hydraulic fluid.

CHAPTER 6

HYDRAULIC TURRETS

1. (*a*) Martin 250 CH–3

   Third modification of the model
   Hydraulically operated
   Cylindrical shape
   Armed with two .50 caliber guns
   Manufactured by Glenn L. Martin Co.

   (*b*) ERCO 250 TH–2

   Second modification of the model
   Hydraulically operated
   Tear-drop shape
   Armed with two .50 caliber guns
   Manufactured by Engineering and Research Corporation.

2. (*a*) One type is shaped so that both guns and turret can pivot horizontally (in azimuth) as well as vertically (in elevation), whereas the other type is shaped so that the turret moves in azimuth only and the guns move in elevation only.
   (*b*) One type is valve-controlled, whereas the other type is controlled by pump.
3. By varying the direction and rate of flow of the appropriate pump.
4. To prevent the turret from falling forward under its own weight.
5. Hydraulic power is obtained from an actuating panel OUTSIDE the turret.
   The turret can be operated manually without the use of its hydraulic or electrical systems.

CHAPTER 7

THE F4U–1 CORSAIR

1. (*a*) At the top of the engine mount, just forward of the firewall.
   (*b*) Supply line to engine pump.
   Hand-pump supply line.
   System return line.
   Vent line.
2. In the three-point position, with landing gear extended and flaps up.
3. Manifold block. On the forward bulkhead in the cockpit.
4. Landing gear.
   Wing fold.
   Wing flap.
   Engine cooling.
   Gun charging.
   Brakes.
5. Landing gear.
6. Wing fold.

CHAPTER 8

THE SBD DAUNTLESS

1. 1,000 psi.
2. Landing gear.
   Landing flaps.
   Diving flaps.
   Cowl flaps.
   Auto pilot.
   Brakes.

3. Landing and diving flaps.
4. The Dauntless' system uses a time-delay valve rather than a pressure regulator or an accumulator.

CHAPTER 9

THE TBF–1 AVENGER

1. (*a*) Brakes.
   (*b*) All the major units.
2. 1,150 to 1,500 psi.
3. Four.
4. Landing gear and wing flaps.

CHAPTER 10

THE F6F–3 HELLCAT

1. Retractable landing gear.
   Wing flaps.
   Wing lock.
   Cowl flaps.
   Oil-cooler shutters.
   Intercooler flaps.
   Gun chargers.
2. 1,500 psi.
3. System line.
   Landing gear line.
   Wing flap line.
   General line.
4. (*a*) It would fall directly into the slip stream.
   (*b*) Nitrogen.

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